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STATEMENT OF

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DEPUTY ASSISTANT ADMINISTRATOR
FOR TECHNOLOGY UTILIZATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

before the

COMMITTEE ON AERONAUTICAL AND SPACE SCIENCES
UNITED STATES SENATE

Mr. Chairman and Members of the Committee:

It is my pleasure to appear before you to report
on our activities in the NASA Technology Utilization
Program.

INTRODUCTION

The central focus of our program lies in the main-
stream of the growing national interest in the productive
use of our technological resources. As the President
stated in his Science and Technology Message to the
Congress in March 1972:

"Federal research and development activities
generate a great deal of new technology which
could be applied in ways which go well beyond
the immediate mission of the supporting agency.
In such cases, I believe the Government has a

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BEFORE THE COMMITTEE ON (NASA) 134 p

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responsibility to transfer the results of its research and development activities to wider use in the private sector."

This emphasis on technology transfer and the role of technology in our Nation's economic growth and development have been the subject of much discussion. We recognize the difficulty of specifically quantifying this contribution, yet it is intuitively considered to be substantial. A NASA study of the downstream economic consequences of research and development has been completed and reviewed. It is attached as Appendix A. Among its significant conclusions, the study found that a dollar invested in research and development returns more than seven dollars to the economic mainstream over an eighteen-year span.

PROGRAM OBJECTIVES

Maximizing the contribution of technology through increasing its productive use is the goal of the Technology Utilization Program. Our program objectives remain as previously stated to the Congress. They are:

- to expedite application of new technology, by compressing the time required from

generation of advanced technologies to their use in the economy.

- to encourage the widespread use of NASA technology in other sectors of the economy.
- to understand more fully and to optimize the technology transfer process and its impact.

PUBLIC SERVICE PROGRAMS

We are continuing our program of technology transfer to the public sector, working with a variety of state, local, and federal government units and with other public service agencies to identify problems on which NASA technology may be brought to bear. Our Application Teams work on problems in biomedicine, air and water pollution, fire safety, housing and urban development, transportation, law enforcement, criminalistics, postal service and mine safety.

These NASA teams serve as principal links between NASA sources of technology and the potential users of aerospace technology. Together with these non-aerospace

users, or clients, the Application Teams carefully define those technical problems which are important to the user and which appear to lend themselves to aerospace-derived solutions. When the problem is identified, the Application Teams search aerospace technology files for relevant technology. At the same time specialists at NASA laboratories and field centers are systematically canvassed for potential solutions.

A successful search for potential solutions is followed by experimental efforts to prove out proposed solutions. All along the way, the applications process operates on a basis of partnership between NASA and the potential user.

In the past year, the developing relationships with users have led to more and more intergovernmental cooperation at federal, state and local levels. We have always worked through those agencies which have mission responsibility for public sector problems, and have continued these relationships in this past year with agencies such as the Veterans Administration,

the Department of Housing and Urban Development, the Environmental Protection Agency, the National Institutes of Health, and others at the federal level. State and local units are also heavily involved. As one example, at the request of the City of New York, we have established an experimental type of Application Team in the city to work directly with technical problems encountered by the City's operating units. Although the Team has only been in operation a few months, some potential technology transfers have already been identified. In one case, the City's Board of Education has decided to adopt a NASA-developed school alarm system, using a pen-sized ultrasonic transmitter and a master receiver panel, which permits teachers to give warning of danger and to request aid. Mayor Lindsay recently announced that the units would be tested in three schools, as one step toward improved order in the city school system.

APPLICATIONS ENGINEERING FOR THE PUBLIC SECTOR

Our program of applications engineering comes into play in cases where the actual development of prototype

devices that can be tested and demonstrated by the user is necessary for culmination of the transfer. Again, public sector problems are the target. Such development projects frequently originate from Application Team activities with users. In other cases, the scientists and engineers in NASA Field Centers submit proposals based on their perceptions of the relevance of their in-house skills and capabilities to public sector problems.

Some examples of Applications Engineering projects, as well as results of our Application Team activities, are described in Appendix B to this report. One example concerns a device originally developed and used by NASA to test astronaut performance skills. The device is called a Complex Coordinator and tests the perceptual and motor skills of a person by requiring him to exercise his hands and feet in coordinated fashion. The device has been used at Duke University to ascertain the degradation of driver skills during exposure to carbon monoxide. These tests were performed under contract to the Environmental Protection Agency.

The California Driver Education Association has tested the same device to demonstrate the effects of alcohol on human performance. The California Highway Patrol has considered the device for screening police candidates before they mount motorcycles. Other possible applications include testing motor skills related to operating equipment or machinery. Medical rehabilitation specialists have suggested that the device might be used as a therapeutic exercising tool for patients. The Small Business Administration has provided funds for a market study, and a minority business, the J.W.M. Corporation of Philadelphia, now offers the equipment for sale.

STATE AND LOCAL GOVERNMENTS

I mentioned that our public sector programs have increasingly dealt with state and local government. We have had a number of opportunities in the past year to participate with other agencies in providing assistance to local governments.

In one instance we cooperated with the Commerce Department's pilot program to fund the states of Illinois

and Connecticut in projects to enhance productivity utilizing unemployed aerospace engineers. One of our six Regional Dissemination Centers worked closely with a group of these engineers in Illinois to solve technical problems and select promising technology for new business opportunities. The aid of the Center was conservatively estimated by the Illinois program as producing value equivalent to twice the cost of the service.

ACQUIRING NEW TECHNOLOGY

Clearly, a transfer program relies on a continuing supply of new technology to the system. To date, a total of more than 23,000 disclosures of technical contributions have been made by NASA contractors, and 2613 were made in 1972. A total of 4000 innovations and inventions have been reported by NASA scientists and engineers. At this time, we are concentrating on the monitoring and reporting of new technology developed in the Skylab and Shuttle programs. Skylab, which will soon be launched, has involved a new technology

reporting plan which has disclosed much new material. For the Shuttle, we are making arrangements to assure that the Shuttle prime contractors pass on new technology reporting requirements to major subcontractors, since there will be major technological development activity carried on by subcontractors in the Shuttle program.

TECHNOLOGY TRANSFER

NASA Tech Briefs, now in their tenth year of publication, remain a very important element of the transfer program. When new technology is reported by contractors and NASA employees, these short, concise summaries serve to first announce that innovation to the public. In 1972, 756 new Tech Briefs were issued, bringing the total to date to more than 5000.

We also continue to publish Compilations, which describe several innovations in specific technical fields, as well as other Special Publications which document technological advances in particular disciplines.

PATENT LICENSING

In the past year, patent licensing has assumed even greater importance as a technology transfer tool.

President Nixon, in his 1972 Science and Technology Message, noted that the new government patent policy would include ". . . a new systematic effort to promote actively the licensing of Government-owned patents and to obtain domestic and foreign patent protection for technology owned by the United States Government in order to promote its transfer into the civilian economy."

NASA has moved quickly to amend its patent licensing regulations. Under these regulations, NASA is in a position to accelerate commercial application of aerospace-related patented inventions and technology by granting exclusive manufacturers' licenses more quickly than was previously possible. Specifically, rather than wait until two years after a patent has been issued, as previously required, NASA can now grant exclusive licenses in appropriate cases as early as nine months after the invention has been announced as available for licensing.

The prime consideration in granting an exclusive license will be whether such a license is necessary

in order to stimulate the investment of private capital necessary to bring an invention to practical application. For instance, a lightweight, non-tippable, radar-reflective life raft was developed at Langley Research Center for use by astronauts. The raft was used by Scott Carpenter at the end of his Mercury "Aurora 7" flight. NASA published a Tech Brief in 1963 and obtained a U.S. Patent for the life raft in 1964. This patent was unexploited for several years in spite of the fact that two non-exclusive licenses were granted. Then, in 1969, an exclusive license to manufacture this NASA-developed life raft was granted to Robert F. Perchard, an individual entrepreneur. Mr. Perchard promoted the further development of a commercially feasible, radar-reflective material meeting his specifications of high detectability and thermal protection. Under a license from Mr. Perchard, the Winslow Company, of Osprey, Florida, manufactures and sells the NASA patented life raft to both Government and commercial users. Of particular interest are sales to the U.S.

Coast Guard, which is also testing the new material for other survival gear uses. The editor of Boating magazine calls Mr. Perchard's work a "breakthrough for survival" and says that he "has earned a vote of gratitude from boatmen everywhere."

INDUSTRY ACTIVITY

As we have previously pointed out to this committee, significant technology transfer takes place within companies which have developed capabilities and new technologies through research and development contracts. Frequently the movement of skilled people from aerospace divisions to commercial product groups is deliberately planned to achieve technology transfer. The General Electric Company has provided us with a statement -- attached as Appendix C -- which details how, in their experience, this process works.

REGIONAL DISSEMINATION CENTERS

NASA's principal active program for facilitating the flow of aerospace technology to the private sector is based on our six Regional Dissemination Centers.

The Centers, which collectively represent 47 years of experience in working with industry, continue to work on a one-to-one basis with commercial clients. The system is relatively simple: industrial customers bring their technological problems to the Regional Dissemination Center in their region, and the Regional Dissemination Center provides the customer with the results of any pertinent NASA research. Not only does the Regional Dissemination Center furnish the basic information but, in many cases, it also arranges direct contact with the NASA scientist or engineer who can give expert personal guidance or comments on the problem.

Industry is increasingly turning to the Centers for assistance, and their existence is becoming better known as their experience increases. In 1972, the Centers served over 2,150 industrial users. The most experienced NASA Regional Dissemination Center, which is located in Indiana, has completed ten years of service to clients in the midwestern region. We estimate that since their establishment, the six Centers have served a total of

approximately 8,000 different industrial units. Also, it is important to note that 49% of the companies served last year were small businesses; we have carefully maintained the capacity to respond to small firms as well as the nation's largest industrial companies.

Several cases of transfer reported to us in the last year (described in Appendix D) that resulted from the Regional Dissemination Center program illustrate the implications of this program for productivity and economic development. One such case concerns the Franklin Electric Company, a small manufacturer. Since 1966, Franklin has used our Center in Indiana to help to economically solve its manufacturing and production problems. Recently, Franklin was experiencing problems with carbon bearings in its line of gasoline submersible motors. NASA had encountered and successfully solved similar problems and Franklin was able to apply the NASA solution to its own products.

A list of the Regional Dissemination Centers and the Application Teams is attached as Appendix H.

NASA COMPUTER PROGRAMS

Our program to make NASA-developed computer programs publicly available -- known as the COSMIC program (Computer Software Management and Information Center) -- has continued its successful operation. The current inventory of nearly 1200 programs enables customers to avoid costly duplication in their own operations by using software developed by NASA for aerospace applications. Approximately 4150 software packages were distributed in 1972, including some contributed by the Department of Defense through an interagency agreement.

A study of users of programs disseminated by COSMIC was recently completed. The study considered 1174 users of these programs. Twenty-one percent of the users reported that the availability of these NASA programs provided a capability that was otherwise unobtainable: the applications could not have been accomplished by alternative means. Many users reported significant cost savings -- one program, used in the

design of a nuclear power plant, allowed annual savings of \$80,000. Some clients found significant productivity increases, including savings of time and operating cost, and more accurate and complete results than other sources provided.

EVALUATION OF TECHNOLOGY UTILIZATION PROGRAM AND BENEFITS

Our studies of the impacts and benefits of NASA activities, including those resulting from technology transfer, have continued to develop new information which we are making available to the Committee.

We have continued to accumulate those many case studies of discrete cases of transfer, involving the experience of one user or the uses of one specific innovation. Illustrative cases of this type are presented in Appendix E.

The contribution of NASA technology to certain technical fields or segments of industry has also been studied. Some of our reports in the past year -- called Technology Transfer Profiles -- have looked closely at the fields of:

- Nondestructive Testing
- Fracture Mechanics
- Industrial Products, Production, and Practices
- Visual Information Display Systems

Copies of these reports are, of course, available for the Committee's review. These industry-level studies tend to confirm the point made by the earlier mentioned economic study, i.e., that the contribution of mission-oriented research and development to the overall national level of productivity and economic growth is an impressive one.

The complex question of the larger spectrum of impacts of the aerospace program on American life has also been studied. Reports based on these studies have concentrated on certain major areas of human concern and have attempted to gain a better understanding of some of the more subtle ways in which these areas are affected by NASA programs. New studies have been recently completed, and earlier studies updated, in the following areas of human concern:

- Health Care
- Transportation
- Communication
- Safety
- The Environment

As an example of this type of study, the Health Care report is attached as Appendix F to this statement; we will be pleased to submit the others for the Committee's use. Also, we have prepared for the record a list of all such studies of NASA impacts and benefits published in the past two years, including evaluations of our own program. This list is Appendix G.

PROGRAM COST

The broad range of activities described above indicates some of the programs undertaken and progress made. To continue these activities, our funding request for FY 74, a total of four million dollars, is broken down as follows:

	(Thousands of Dollars)		
	<u>FY 72</u>	<u>FY 73</u>	<u>FY 74</u>
New Technology Identification, Evaluation and Publication	950	675	720
New Technology Dissemination	1,180	1,125	1,125
Technology Applications	2,370	1,790	1,755
Program Evaluation and Benefits	<u>500</u>	<u>410</u>	<u>400</u>
Total	\$5,000	\$4,000	\$4,000

CONCLUSION

During the past year we have moved much farther toward effective technology transfer programs in the public sector. We have had several instances of real cooperation with other agencies at all levels of government, and have found that concerted effort can indeed result in the application of NASA technology to public sector needs. There has been especially encouraging progress in the fields of medicine, transportation, fire safety, housing, environmental protection, and others.

The steady growth of our programs reflects the strides we have made in achieving the awareness and confidence of both large and small businesses. Our

Regional Dissemination Centers have continued their record of service to the private sector, and have been able to assist state and local government units as well. Our computer software dissemination program has had outstanding success in the past two years, and we are pleased that this particularly innovative project, begun more than five years ago, has proven its utility many times over.

NASA's future programs -- especially Skylab and Shuttle -- promise the uninterrupted flow of new technology which will add to that reservoir of knowledge from the Apollo program which has been the mainstay of our transfer programs so far.

Our studies in the area of program evaluation and benefits have been quite encouraging, and continue to show us ways both of refining our own program techniques and of better understanding the role that mission-oriented research and development plays in the continuing development of our Nation's technological progress.

NASA's Technology Utilization Office was established in 1963. After ten years of operation, the technology

transfer program has acquired a reservoir of experience and know-how in this specialized area of knowledge. This legacy of experience, of trying to learn from lessons in a variety of experimental programs conducted over the years, stands us in good stead. We plan to go forward, on the basis of this experience, to what we hope will continue to be a program of great value to the Nation.

APPENDIX A
to the
STATEMENT OF
Clare F. Farley
Deputy Assistant Administrator for
Technology Utilization
A Report:
"Economic Impact of Stimulated Technological Activity."
Management Summary Volume

ECONOMIC IMPACT OF STIMULATED TECHNOLOGICAL ACTIVITY

FINAL REPORT - SUMMARY
7 April 1970 - 15 October 1971

Contract No. NASW-2030

MRI Project No. 3430-D

For

National Aeronautics and Space Administration
Headquarters
Technology Utilization Division
Washington, D. C. 20546

PREFACE

This is one of five volumes which present the findings of a research inquiry into the Economic Impact of Stimulated Technological Activity. The titles of the volumes are:

Part I - Overall Economic Impact of Technological Progress--Its Measurement

Part II - Case Study--Technological Progress and Commercialization of Communications Satellites

Part III - Case Study--Knowledge Additions and Earth Links from Space Crew Systems

Summary Volume--Economic Impact of Stimulated Technological Activity

Bibliography

The research was sponsored by the National Aeronautics and Space Administration Office of Technology Utilization under the terms of Contract NASW 2030. The project staff of Midwest Research Institute included: Robert E. Roberts, Howard M. Gadberry, Robert E. Fleisher, Lawrence L. Rosine, E. Duane Dieckman, and Linda L. Crosswhite.

Principal consultants were Dr. M. Jarvin Emerson and Dr. Thomas J. Weiss for Part I, Mr. Edwin J. Istvan for Part II, and Mr. R. A. Bambenek for Part III. The project team benefited from the suggestions of an advisory panel composed of Dr. Randall T. Klemme, Dr. Charles N. Kimball, Dr. Kenneth C. Wagner, Mr. James A. Alcott, Dr. Richard Marsten, and Dr. Werner Z. Hirsch. The contributions of Dr. Donald Silverman, an ex officio member of the panel, are also acknowledged.

Acknowledgement is also made to the vital contributions of perhaps one hundred or more scientists and engineers interviewed during the course of the study. Their cooperation and that of their employers--NASA Centers and private contractors--was essential.

Special thanks are due to Joseph M. Carlson, the NASA Project Officer, and Ronald J. Philips, Director of the Technology Utilization Division, throughout most of the project life.

The findings and judgments expressed in the report are those of the MRI project team and do not necessarily reflect the view of the National Aeronautics and Space Administration or those of any company or individual surveyed.

Approved for:

MIDWEST RESEARCH INSTITUTE



John McKelvey, Vice President
Economics and Management Science

22 November 1971

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ECONOMIC CONSEQUENCES OF STIMULATED
TECHNOLOGICAL ACTIVITY

"The nation's technological capacity, which is conceptually analogous to the capacity of its physical plant, is unquestionably a nation's most important economic resource. By the same token, the rate at which its technological capacity grows sets what is probably the most important ceiling on its long-term rate of economic growth.

The rate of growth of a nation's technological capacity depends jointly upon the rate at which it produces new technology and the rate at which it disseminates the old."

Jacob Schmookler

Invention and Economic Growth
1966

OVERVIEW

The degree to which a nation can satisfy its collective and individual wants is dependent upon the wealth of the nation and its citizens. The accumulation of economic wherewithal is obtained through combinations of labor, capital, and technology. All three inputs are essential but it is through technological progress that the productivity of labor and capital are increased to obtain more output per unit of input and, consequently, greater per capita wealth. The United States leads the world in the generation and application of technology. Our technological progress poses certain dilemmas, but is also the source of much of the economic power we are bringing to bear on societal deficiencies--deficiencies that many less wealthy nations cannot afford to consider, much less mount assaults upon.

This volume highlights the findings of a research inquiry into the relationships between technological progress and economic development, with emphasis on the several ways in which NASA research and development has aided in the accumulation and commercial application of new or improved scientific and technological knowledge.

Scope of Research

The research undertaken had three separate, but related parts: Part I was an examination of the importance of technological progress in the generation of national economic growth. The focus was on aggregate economic effects of technological progress--with technological progress being viewed abstractly as one of the principal growth-inducing forces operating in the economic milieu. Part I was concerned with effects: the economic effect of technological progress, the effect which R&D has on technological progress, and the effect of NASA on the nation's R&D spending. Specifically, this portion of the study was based on an econometric examination of the U.S. economy during the last 20 years to identify and measure the portion of growth which can be attributed to technological progress. Part I also examined the relationship between R&D and technological progress and, finally, made some tentative estimates of the relative effectiveness of NASA R&D expenditures in generating economic growth via technological progress.

Part II was a case study of the process whereby technology is developed and commercially applied. It was designed to undergird--by example--the findings of the econometric study. It was also intended to illustrate the extreme complexity of the application process--in particular, that any large technological undertaking produces both direct and indirect commercial applications, that these come in a wide variety of forms and types, that countless individual increments of technological progress are combined in any application, that there are many participants in the process--no one of whom can claim sole credit--and finally to examine the several roles that a mission-oriented research and development agency such as NASA plays in the application process.

The specific case study undertaken was of the R&D programs and application endeavors which have culminated in commercial communication via satellite.

Part III of the report was an illustration of ways in which a NASA undertaking has contributed to the nation's scientific and technical knowledge reservoir--the reservoir which is drawn upon and extended by any move toward application. The intent was to demonstrate that a large body of knowledge is accumulated in the process of satisfying mission-oriented program requirements and that this knowledge is retained for use by others for other purposes. The research procedure was again a case study. In this instance the focus was on what we had to learn to keep man alive and productive in space--with emphasis on those things which have relevance from one form or another to earthly problems.

Thus, in three separate but interlocked studies, MRI attempted to touch upon major elements in the progression from science through technology to viable application in the economic realm: Part I measures the economic effect of technological progress. Part II illustrates the process whereby technology is developed and commercially applied (covering the invention/innovation portion of the spectrum). Part III shows that an inherent aspect of mission-oriented R&D is the generation of new or improved knowledge--in many fields: basic phenomena, applied science, engineering, design, materials, processing, etc. And, that this knowledge is added to the nation's knowledge bank for withdrawal when demand and the state of industrial practice evolve to the point where the technology will be applied.

PART I

OVERALL ECONOMIC IMPACT OF TECHNOLOGICAL PROGRESS--ITS MEASUREMENT

A. BACKGROUND

The central questions toward which this phase of the report was addressed are:

1. What is the role of technological progress in national economic growth?
2. What factors determine the rate of economic growth due to technological progress?
3. Can the relationships between technological progress, its determinants, and subsequent economic growth be measured--quantitatively?
4. And, how do the research and development activities of the space program tie into the preceding questions?

Before World War II, there was little need to ask such questions at the national level. Most development was performed by the individual inventor or by industrial laboratories supported by company funds. Choices as to whether or not to allocate resources to development and how to distribute resources among projects were made within individual companies. Most of the nation's research effort was performed at universities as an adjunct to graduate education. National priorities had little direct influence on the allocation of resources to R&D, and the scale of R&D was small enough that the formulation of precise relationships between R&D and the economy lacked urgency.

R&D grew dramatically following World War II under the stimulus of the Cold War and the race to combine atomic weapons with rocketry. Massive mission-oriented R&D programs were mounted, using as their model the Manhattan Project of World War II. All facets of research--basic and applied--as well as development and sophisticated production plus scientific and engineering education underwent huge federally funded expansions. A strong scientific and technological capability became an essential instrument for national survival--decisions to allocate resources to R&D were made on the basis of necessity.

By the late 1950's, when the nation's first large-scale civilian mission-oriented R&D agency--NASA--was created, the economic effects of such undertakings were receiving explicit, if imprecise, recognition. At about the same time, the short-term and regional economic impacts of expanded R&D began to receive widespread recognition. Community after community strove to become another Route 128, or San Francisco Bay Area, or Huntsville. The immediate benefits of a local R&D complex were clear. Less clear were the processes whereby R&D led to new or improved processes, products, and services. But more important to the purposes of the present portion of this report, the theory, methodologies and empirical data needed to measure quantitatively the cumulative effect over time of the product and process advances were notably deficient.

During the 1960's a number of theorists and researchers undertook to improve our ability to measure the economic impact of technological advances, for it had become clear that technology was a large and powerful force in the accumulation of national wealth. Pioneering work by Solow, Kendrick, and Denison was amplified and extended by a number of others. Much progress has been made, but the fact remains that we got to the moon in a decade, but are, as yet, unable to fully measure the present and future economic impact of the science and technology accumulated on the way to the moon (or the aggregate effect of technological progress in general). Our present capability to measure the relationship between technological progress and R&D is even less precise.

Yet, national decisions with respect to the allocation of resources to and within R&D are being and will be made. These decisions cannot be postponed until precise measurements of their effects are possible. Thus, the intent of this part of the study was to provide--from within the existing state of the art--some measurements of technology's contribution to this nation's wealth during recent years and the role of R&D in generating growth through technological progress.

B. RESEARCH APPROACH

The investigations were performed at the national economic level. We were exploring the aggregate effects of technological progress rather than those stemming from the individual inventions or innovations. Inadequacies in all existing macro-economic yardsticks forced the study to focus on the "cost savings" effects, i.e., increases in the productivity of labor and capital achieved through technological progress. The many improvements in the quality of goods and services due to research and development are not adequately reflected in existing aggregate economic series and cannot be directly measured.

Given these restrictions on the scope of the study, six research tasks were performed:

First, we adopted a definition of technological progress that is consistent with how progress occurs and how it is generally perceived to occur. The definition presumes that all increases in output not attributable to added quantities of labor and capital are due to technological progress; i.e., all quality improvements in labor and capital are traceable to technological progress.

Second, within the framework of the definition of technological progress and neo-classical economic growth theory, a suitable macro-economic production function was structured.

The adopted production function states that technological progress acts in a multiplicative rather than an additive fashion in augmenting labor and capital in the output-generating process. The general form of the production function employed is:

$$Q_t = A_t f(K_t, L_t)$$

where:

Q_t = Output in time period t

K_t = Capital utilized in time period t

L_t = Labor expended in time period t

A_t = Level of technology applied in time period t .

Third, the technology index^{1/} implicit in the production function was used to assess quantitatively the impact of applied technology on economic growth and output.

Fourth, having determined the level of technology and resulting output, we related technological progress generating activities such as research and development, economies of scale, education, etc., in a mathematical model. Here, the determinants of technological progress were linked to the effect of their stimulus in terms of incremental economic output.

^{1/} The index, A_t , represents the technology being applied in the production process through time. It is arrived at through analysis of actual output and output possible with labor and capital quality--i.e., embodied technology--fixed at a base year.

With respect to growth in output in the private, non-farm sector of the economy traceable to R&D--which was denoted $G(R\&D)$ --we hypothesized the following relationship:

$$G(R\&D)_t = f(R_t)$$

where:

R_t = The weighted sum of past R&D expenditures for year t .

Mathematically, the weights are expressed:

$$R_t = w_0 r_{t-0} + w_1 r_{t-1} + w_2 r_{t-2} + \dots + w_i r_{t-i} + \dots + w_{18} r_{t-18}$$

where:

w_i = Weight for the i th year lag, and

r_{t-i} = R&D expenditures in the year $t-i$.

Thus, R_t is a reflection of the current year's R&D activity plus the effective value of each of the past 18 years of R&D expenditures. Conceptually, R_t can be considered the effective investment in R&D "at work" in year t . The 18-year payout period and the payout pattern within the period were derived from several comprehensive and respected surveys of industry's pay-back expectations for R&D spending and new product lifetimes.

Fifth, through the use of statistical analysis, we empirically determined quantitative relationships existing between growth due to technological progress and determinants of technological progress.

Finally, within the preceding analytical framework, we examined the economic impact associated with the technological stimulus provided by the space program.

C. FINDINGS AND CONCLUSIONS

As have others before us, we found technological progress has been a powerful force in economic growth. Our study considered:

- * That technology is one of the factors of production--along with labor and capital--with which the output requirements of the nation are satisfied;

- * That what we term technological progress is responsible for improvements in the quality or productivity of labor and capital;

* That technological progress results from the introduction of new or previously unused knowledge into the production process;

* That there are many mechanisms by which knowledge is productively applied, including: Improved worker skills, improved machine design, improved management techniques, and so on.

Measuring the effect of technological progress--so defined--during the 1949 through 1968 time period, we found that:

* The technology added to the nation's production recipe after 1949 accounted for 40 percent of the real increase in private, non-farm output during the period.

* Collectively, total output for the period was about \$8.2 trillion. If there had been no increase in the level of technology used after 1949, the stock of labor and capital applied would have only yielded a cumulative output of \$6.9 trillion. Thus, the leverage on the other two factors of production by technological progress permitted almost 20 percent more output than might otherwise have been achieved with the same quantity of labor and capital.

* Throughout the period the technology factor in the production function increased at a compound rate of 1.7 percent per year. By the end of the period--in 1968--the compounding growth of technology had reached a point at which technological improvements beyond 1949 levels were accounting for 37 percent of output (Figure 1).

Although it is possible to dissent on certain grounds about the exact amount of productivity gains due to technology, the major conclusion is clear. Without the increase of technology and its introduction into the production recipe, this nation would be substantially less wealthy than it is. Much of the economic wherewithal we are now attempting to apply toward the solution of pressing domestic problems is the product of applied technological progress. To expand this economic capacity for problem resolution, this nation must continue to allocate resources to enterprises which generate technological progress and encourage its productive utilization.

This brings us to the second set of findings--those related to the sources or determinants of technological progress. The theoretical and empirical foundation for these assessments is less definitive than for the preceding findings. However, there is general agreement on a list of forces important in the generation of technological progress. The forces are highly interactive but, for analytical reasons, were treated independently. Our findings indicated that most of these forces were of insignificant effect during the relatively short time period under study.

OUTPUT AND GAINS RESULTING FROM TECHNOLOGICAL PROGRESS
(1949-1968)

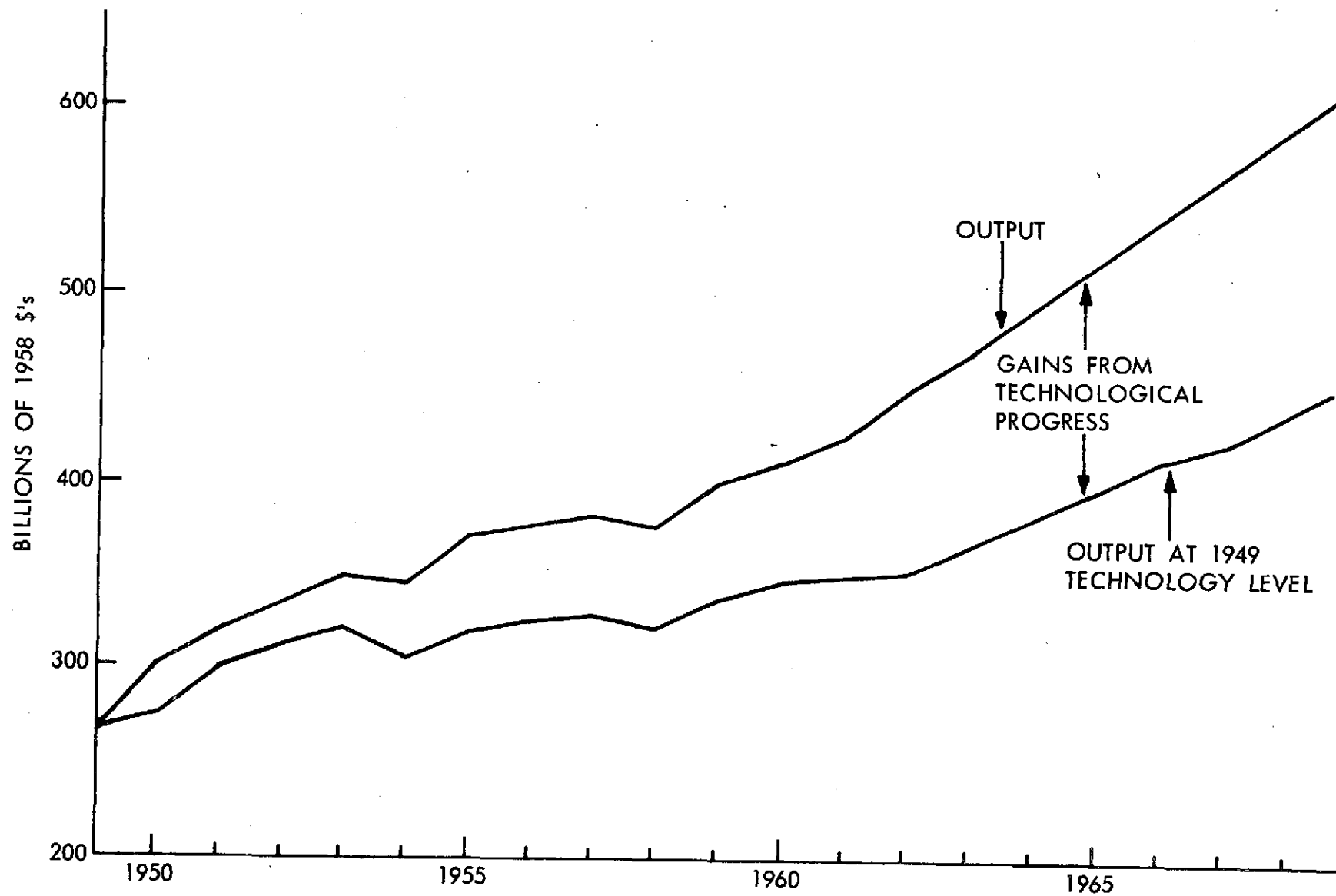


Figure 1

However, three factors--the sex mix of the workforce, education, and R&D--were found to be important determinants of economic gains through technological progress during the Post-World War II period. The first, sex mix, is the product of increasing participation by females in the workforce and increasing productivity by distaff employees. Improvements in this factor during the period accounted for 4 percent of the total gains due to technology. Improved worker productivity through higher educational levels contributed approximately 36 percent. The balance of the technology-induced gain--60 percent--was attributed to R&D after having ascertained that other possible determinants had no measurable or identifiable impact.

The relationship between R&D- and technology-induced economic gains was explored on a distributed-lag basis. Lag distributions between R&D expenditures and initial pay-back and final pay-out in the form of national economic gains were constructed from industry estimates and experience, but when subjected to statistical tests the relationships exhibited reasonably good explanatory power. The findings were that:

On the average--each dollar spent on R&D returns slightly over seven dollars in technologically induced economic gains over an 18-year period following the expenditure.

This finding leads to the strong conclusion that, on the average (including good, bad, and indifferent projects), R&D expenditures have been an excellent national investment.

The final set of findings relates to the economic impact--via technological progress--of NASA's R&D programs. Assuming that NASA's R&D expenditures had the same pay-off as the average, we found that:

The \$25 billion, in 1958 dollars, spent on civilian space R&D during the 1959-1969 period has returned \$52 billion through 1970 and will continue to produce pay-off through 1987, at which time the total pay-off will have been \$181 billion (Table 1). The discounted rate of return for this investment will have been 33 percent.

As noted, the preceding finding was based on the assumption that NASA R&D spending has an average pay-off effect; there is strong preliminary evidence that the exacting demands of the space program may produce greater than average economic effects due to increased technological leverage. This comes about because NASA allocates its R&D dollar to the more technologically intensive segments of the industrial sector of the economy. The weighted average technological index (A_t) of the industries which perform research for NASA is 2.1, while the multiplier for all manufacturing is 1.4. Although there are a number of conceptual and procedural limitations to the construction of industry-level technological multipliers, the spread seems large enough to support the view that highly technological undertakings, such as the space program, do exert disproportionate weight toward increased national productivity.

TABLE 1

G(R&D) GENERATION PATTERN RESULTING FROM NASA R&D
(1958 \$'s in Millions)

	<u>1959</u>	<u>1960</u>	<u>1961</u>	<u>1962</u>	<u>1963</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>Annual</u> <u>G</u>	<u>Cumulative</u> <u>G</u>
Annual NASA R&D	128	351	602	1,261	2,446	3,315	3,982	4,283	3,414	3,116	2,518		
<hr/>													
G (R&D) Generated													
1959	1											1	1
1960	6	2										8	9
1961	21	16	4									41	50
1962	48	57	28	8								141	191
1963	84	132	97	58	16							388	579
1964	118	231	227	204	113	22						915	1,495
1965	138	324	397	475	395	153	26					1,909	3,404
1966	138	378	556	832	922	536	184	28				3,574	6,978
1967	120	378	649	1,165	1,614	1,250	644	198	22			6,040	13,016
1968	93	331	649	1,359	2,259	2,187	1,501	692	158	21		9,250	22,267
1969	64	256	567	1,359	2,636	3,062	2,627	1,615	552	144	17	12,898	35,167
1970	40	177	439	1,187	2,636	3,572	3,678	2,826	1,287	504	116	16,462	51,629
1971	22	109	303	919	2,303	3,572	4,291	3,956	2,253	1,175	407	19,311	70,932
1972	11	61	188	634	1,782	3,122	4,291	4,615	3,153	2,056	949	20,864	91,805
1973	5	31	105	393	1,231	2,415	3,750	4,615	3,679	2,878	1,661	20,764	112,566
1974	2	14	53	219	763	1,668	2,901	4,033	3,679	3,358	2,326	19,016	131,582
1975	1	5	24	110	426	1,034	2,003	3,121	3,215	3,358	2,713	16,010	147,592
1976		2	9	50	214	577	1,242	2,155	2,487	2,934	2,713	12,384	159,975
1977		1	3	20	96	290	693	1,336	1,718	2,270	2,371	8,797	168,773
1978			1	7	38	130	348	745	1,065	1,568	1,835	5,737	174,509
1979				2	13	52	156	374	594	972	1,267	3,430	177,940
1980					4	18	62	168	298	542	785	1,878	179,818
1981					1	5	21	67	134	272	438	939	180,757
1982						1	6	23	53	122	220	426	181,167
1983							1	7	18	49	99	174	181,353
1984								1	5	17	39	63	181,419
1985									1	5	14	19	181,438
1986										1	4	5	181,443
1987											1	1	181,444
TOTAL	914	2,506	4,298	9,002	17,462	23,665	28,427	30,576	24,372	22,245	17,976	181,444	

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PART II

CASE STUDY: TECHNOLOGICAL PROGRESS AND COMMERCIALIZATION OF COMMUNICATIONS SATELLITES

The process whereby technology is developed and applied in the economic realm includes one of the most complex sets of interactions encountered in today's world. Three elements must be present before new technology is applied: the technology itself must be in existence, there must be a need for the technology, and some organization or combination of organizations must be willing to undertake the risk and investment necessary to bring the technology to the market. In addition, technological progress is a continuous process with no discrete beginning or ends. It is composed of a few major and countless small incremental advances which are constantly being combined and recombined in a bewildering array of ways to satisfy public and private demand. Technology also follows a variety of paths--direct and indirect--in its movement toward application. Only rarely is the application of a technological advance confined to the use for which it was originally developed. The speed and direction of early and subsequent applications is largely conditioned by the mix of participants--public and private--and the roles each adopts in the process. The evolution of needs into viable markets and the structural characteristics of relevant industrial sectors are also important in the pace of technology's application; as a consequence, multiple relationships among consumers, industry and government are inherent in the process.

In short, the technology application process, by which the economic effects measured in Part I come about, almost defies an organized, comprehensive treatment. But, some appreciation of the application process and its complexity is necessary if we are to insure a continuing flow of economic benefits from technological progress and avoid the widely discussed penalties of such progress. Faced with this situation the present researchers chose to undertake a case study of a significant technological endeavor, the intent being to illustrate--with specific examples--significant facets of the process, something of its pervasiveness, the kinds of contributions a national R&D agency, like NASA, makes to the process, and the several types of economic applications which flow from or are accelerated by such a technological undertaking.

Since communication via satellite is clearly an example of technological progress made during the last decade and a half, an examination of the R&D effort culminating in this commercial application was selected for case study. In addition, communication via satellite is the first major direct commercialization of technology to result from the national space program.

A. STUDY CONSTRUCTION

As noted, any application of technology is the gathering together of many technological threads to meet the objective at hand. And, most of the individual technological threads also find applications beyond those of the original objective. A principal purpose of the case study was to illustrate that both of these characteristics of the process do occur and how they occur.

Thus, Part II had two segments: the first being an examination of the technological requirements which had to be satisfied before the several types of communication by satellite could be achieved, an examination of the national R&D program which has and is leading to the satisfaction of the requirements, and the technical contributions of and roles played by NASA in this R&D process; the second being an examination of ways in which participants (NASA contractors) in the NASA portion of the R&D effort (in particular the SYNCOM, ATS, and companion supporting research programs) have applied the technological capabilities they acquired or augmented during the R&D phase in the resulting commercial communication by satellite market and other markets.

B. RESEARCH PROCEDURE

The major research steps undertaken were:

1. An examination of the several categories of services which can be provided by communications satellites.
2. A grouping of these services into four broad types for subsequent investigation. The types selected were: International--Intelsat/Comsat; Broadcast Distribution--transmission via satellite to major centers with transmission to ultimate users via conventional terrestrial links; Direct--transmission to many users direct from the satellite; and Mobile--communication via satellite with mobile users, such as in air traffic control.
3. A delineation of the major technical characteristics or requirements associated with each of the four types of applications.
4. An examination of the contributions which NASA programs--particularly, SYNCOM and ATS--have made to the satisfaction of the requirements.
5. Estimates of the economic impact associated with the four types of applications.

6. Identification and interview of a representative set of contractor companies that participated in the SYNCOM and ATS programs to identify the extent and ways in which they participated in the commercialization of satellite communications, and in the indirect application of the technological capabilities they accumulated during their participation in this facet of the space program.

Although at least 277 firms have participated, as prime contractors, in the communications aspects of NASA's SYNCOM and ATS programs, the resources allocated to this project dictated that only a few could be included in the survey sample. Fourteen were chosen following an intensive sample selection process. Sample selection was governed by the need to obtain as representative a cross section of participating companies as possible, i.e., large and small firms, satellite and ground station contractors, aggressive and not so aggressive firms, etc. Two firms which were not prime NASA contractors were added to the sample. One is a direct spin-off from one of the prime contractors; the other is a newly formed company that has utilized satellite communications technology in a rather unusual way to assemble and market a marine navigational system. The firms selected were:

Ampex Corporation, Redwood City, California
Bendix, Towson, Maryland
Electronic Communications, Inc., St. Petersburg, Florida
General Dynamics, San Diego, California
General Electric, Valley Forge, Pennsylvania
Hughes Aircraft, Culver City, California
International Telephone and Telegraph (IT&T), Nutley, New Jersey
Martin-Marietta, Orlando, Florida
Rantec Division of Emerson Electric, Calabasas, California
Satellite Positioning Corporation, Encino, California^{1/}
Sylvania, Waltham, Massachusetts
TRW, Redondo Beach, California
Watkins-Johnson, Palo Alto, California
Wavecom, Northridge, California^{1/}
Westinghouse, Baltimore, Maryland
Wiltron, Palo Alto, California

C. FINDINGS SUMMARY

It is extremely difficult to summarize the findings of this case study because the intent was to provide many concrete examples of the forces operating in the technology application process. However, some of the major elements reported on in Part II are:

^{1/} Not prime contractors.

1. Commercial applications and technological requirements. The four general types of commercial application of communication via satellite are described in terms of the generic technological requirements or characteristics of each. The first commercialization was in the International system which came in the form of the Intelsat Consortium of which the Comsat Corporation is the U.S. partner. Since the beginning of service in 1965, this system has grown to serve over 40 nations and plans call for service to almost 60 nations by 1974.

The first domestic Broadcast Distribution system will be the Canadian Telesat system scheduled for operation in 1973. In the U.S., eight applications to provide various mixes of domestic service are pending before the Federal Communications Commission. There are no commercial plans for Direct domestic systems, as yet, although a demonstration experiment for such a system in India is planned for 1974. The first all-commercial system of the Mobile type will be in air traffic control and navigation. A prototype system for trans-Atlantic flights is planned for 1975, with service over the Pacific following a year later.

Table 2 summarizes the technological requirements of the four classes of application.

2. Technological history of communications satellite research and development. The significant programs which contributed to the satisfaction of the technical requirements are described in the basic MRI report, as are the technical content of each program, and the advances associated with each. Particular emphasis is placed on the ECHO project--a passive communications satellite, TELSTAR and RELAY--medium altitude active repeater satellites and the ADVENT, SYNCOM, and ATS programs--synchronous communications satellites.

The purpose of this historical review is to illuminate some of the key technical developments that led, cumulatively, to our present knowledge and capability in the communication satellite field. The review demonstrates that dramatic progress has occurred across a broad technological front. This is illustrated by the fact that we have had a commercial communication satellite system in operation for six years, while only slightly more than 10 years ago many experts had serious doubt that:

* Satellites could be placed in synchronous orbit before 1970.

* Satellites could survive in space, and operate long enough to be economically viable.

* The quality of satellite communications transmissions would be acceptable.

* The cost of satellite systems would be competitive with traditional earth-based communications.

TABLE 2 — REQUIREMENTS FOR FOUR TYPES OF COMMERCIAL COMMUNICATIONS SATELLITES

TYPE OF SERVICE	TOTAL SYSTEM		SPACE SEGMENT						EARTH SEGMENT			
	SYSTEM CAPABILITY (TV, Voice Data, Etc.)	OPERATING CHARACTERISTICS	ORBIT, STABILIZATION, STATION KEEPING	SATELLITE POWER	SATELLITE ANTENNA	SATELLITE TRANSPONDER	CHANNEL CAPACITY	DOWN-LINK FREQUENCY	GROUND STATION TRANSMIT ANTENNA	UP-LINK FREQUENCY	GROUND STATION RECEIVE ANTENNA	GROUND STATION RECEIVER
INTERNATIONAL SATELLITE SYSTEM (Point-to-Point)	All types of service sold by international carrier (TV, voice, record data).	Multiple mode, multiple access. System wide interconnectivity. Channel preassignment plus demand assignment, eventual diversity. Traffic switching, automatic accounting.	Spin stabilized, geostationary or despon platform, 7-10 years of station keeping 1-2 degrees of stabilization sufficient.	Relatively low power on each down-link channel. 100-600 w DC. Has been power limited in past. Future may be bandwidth limited.	May be beamed for global coverage but high density routes could use 4-degree beams to ground. Polarization diversity in future.	Multiple access. Non-return to baseband. Separate transponders ensure against total failure and reduce interference and inter-modulation.	Multiple channels (3,000-9,000) for best utilization of satellite. 10-20 TV channels are possible. (300-800 voice channels per transponder.)	3.700-4.200 GHz used or present. Higher frequency gets more gain from same area of antenna. (Millimeter waves future possibility.)	Large high gain directional 80-100 ft dish. Minimum side-lobes reduce interference to other satellites and terrestrial systems.	5.925-6.425 GHz used by Intelsat but others available. Orbit control and telemetry may use lower frequencies. Millimeter waves future possibility.	Same as transmit.	High gain, high technology with wide bandwidth capability. Weak satellite signals require low noise design. Cooled parametric amp.
BROADCAST DISTRIBUTION (Point-to-Multi-Point)	Primarily voice and TV but data and telephone possible in joint venture. Domestic system. Canadian Telesat is example. Eight U.S. applications for consideration.	Several dedicated broadband channels (network TV). Multiple tariffs for real-time or delayed transmission. Variable capacity data-links.	Stable platform on a dual spin body. Stabilized to 0.5 degree. May be desirable to remove from orbit at end of life.	Medium power 1-2 kw DC. Relatively high power per down-link. Solar-array paddles, power converters, slip rings.	Directional to region (i.e., Rocky Mountain States) or one country (Canadian system). Beam shaping or multiple spot beams.	Limited or assigned access from earth stations. Multiple transponders for mixed users (i.e., broadcast networks, law enforcement, data).	10 or more channels of TV. These may be traded for teletype, voice, data, domestic common carriers, or other. 10,000 or more narrow channels.	Special frequency allocations or present microwave assignments.	Large high gain directional dish. Minimum side-lobes.	Any available microwave frequency. (Possible future use of millimeter waves.)	May be high gain, high technology or small 10-30 ft antenna (later for CATV or ETV/ITV systems).	High gain, high technology for rebroadcast. Unattended converters to feed cable systems for CATV.
DIRECT BROADCAST SATELLITES (Point-to-Wide Area)	TV and voice direct to home or community. ETV, ITV, news, weather, culture. May be part of another hybrid system.	Mixed system, real-time or delayed. Facsimile "news." Many modes may be used. Human interfaces.	Control over stabilization to 0.2 degree. Low thrust station keeping. Control over flexible body interactions.	High power in few channels. 5-12 kw DC. Large solar cell arrays. Slip rings. Power converters, distribution. Fuel cells possible for power.	Regional, covers one country or state (i.e., India, Hawaii, Alaska). High gain to simple receivers. Large deployable 30-60 ft arrays.	Limited or assigned access. High transponder power, high output power final stage.	Possibly one to three channels of high power utilizing most of DC primary solar cell output.	Some proposed frequencies are 0.8, 8.4, 12.2, 2.5 GHz. (These are converted down to standard TV channels at the receivers.)	Large high gain directional dish. Minimum side-lobes.	Available microwave frequency. (Possibly millimeter wavelength in future.)	Low priced, serviceable, unattended with converter. Priced from \$100-\$2,000 (wire mesh dish on wood frame).	Low priced, mass produced, converters for individual TV receivers. State of art TV components. Low as \$100 with antenna.
MOBILE Air Traffic Control (Surveillance Communication and Positioning)	Air traffic control, surveillance, data, position location, communications, warning and display. Remote sensor and weather data.	Diversity or signal redundancy. Digital multiple access. Interrogation and response, on-board processing, discrete address.	Accurate range and range-rate could be desirable in determining position. Platform stabilized to <0.1 degree.	Moderately high power in narrow channel. Solar paddle arrays with 2-axis drive. Must provide strong signal to small antennas and receivers.	Global pattern or to major ocean. Circularly polarized antenna.	Multiple access from aircraft (time-sharing), assigned access from earth controllers. High power to antenna. Sensitive receiver.	As few as two channels of data, four of voice. Some proposals for 300 channels 4 kHz wide.	In 1.6 GHz (L-band) range for link to plane. Satellite to master station link could be in microwave region.	Large dish for master station to satellite.	In 1.6 GHz for plane to satellite link. Microwaves for master control to satellite.	Aircraft send-receive antenna is low profile, circularly polarized. Gain may be 4.0 db Broadbeam, omnidirectional.	Aircraft receiver using solid state circuits. Redundancy may increase system reliability. Display or warn devices.

3. Progress inducing roles of a mission-oriented R&D agency.

Several specific solutions to selected technical requirements, traceable to the SYNCOM, ATS, and companion supporting research programs, are described. Table 3 summarizes some examples. The examples were examined to illustrate the several roles and functions played by NASA in promoting the application of advanced technology to communications needs.

Often the public fails to grasp the multiplicity of roles which governmental R&D agencies play in the technological progress processes. Only in instances where complete NASA-developed systems are commercially applied in toto, is the link to the space program readily apparent. Such clear-cut transfers do occasionally occur, e.g., NASA's SYNCOM III became the commercial INTELSAT I, but they are rare. More subtle relationships are more often the rule. Less obvious roles played by NASA in the development and commercial application of technology include:

Conducting in-house research--An example would be the mechanically despun antenna used in INTELSAT. The initial idea came from Kampinsky's laboratory group at Goddard Space Flight Center. Subsequently, Sylvania laboratories did the actual design and fabrication with key assistance from Ball Brothers, Kearfott, and Mechanical Technology, Incorporated. Antenna performance was validated on ATS III and after additional work Intelsat incorporated the mechanically despun antenna in its third generation of satellites.

Generation of new knowledge and understanding--This is achieved by the performance of scientific experiments which provide the basis for technological improvements. The findings of the earth's triaxiality and the mapping and location of "gravitation grave yards" underlay the selection of positions for geostationary satellites so that they might be maintained on station much longer than their station keeping expendable supplies would otherwise permit.

Classic RFP process--In this process application requirements are defined, technical planning is undertaken, these needs are made known in research organizations and the industrial community through the procurement process. This is a traditional and well established way of motivating innovations which often advance the state of the art.

Initial user or initial adopter--Given knowledge of NASA mission and technical requirements, aggressive firms often undertake developments in anticipation of marketing the results to NASA. Cassegrain feed systems, for example, received early impetus via this role and are now the standard approach for large ground stations. Suppliers now enjoy the Intelsat market.

TABLE 3 - NASA'S PROGRAM CONTRIBUTION TO REQUIREMENT SATISFACTION

TYPE OF SERVICE	TOTAL SYSTEM		SPACE SEGMENT						EARTH SEGMENT			
	SYSTEM CAPABILITY (TV, Voice, Data, Etc.)	OPERATING CHARACTERISTICS	ORBIT, STABILIZATION, STATION-KEEPING	SATELLITE POWER	SATELLITE ANTENNA	SATELLITE TRANSPONDER	CHANNEL CAPACITY	DOWN-LINK FREQUENCY	GROUND-STATION TRANSMIT ANTENNA	UP-LINK FREQUENCY	GROUND-STATION RECEIVE ANTENNA	GROUND-STATION RECEIVER
INTERNATIONAL SATELLITE SYSTEM	SYNCOM First Synchronous Transoceanic TV	ADVANCED SYNCOM ATS-I (Multiple Access) SR&T (Coding and Modulation) (PCM-FM)	SYNCOM II (Altitude Sensors) ATS-I (Spin Stabilization) (Pulse Jet Control) (Polong Attitude)	ATS-I (Low Energy Proton Damage)	ATS-I (Electronic Phased Array) ATS-III (Mechanically Despun Array)	SYNCOM III (Broadband 25 MHz) ATS-I ATS-III (Dual Mode)	SYNCOM II & III ATS-I (Building Block) (Channelization)	SYNCOM II & III ATS-V (Millimeter Waves)	(Cassegrain Feeds) ATS-I ATS-III (Pseudo Monopulse) SR&T	SYNCOM II	SYNCOM II (Margins) ATS-I SR&T	SYNCOM II ATS-I SR&T (Threshold Demodulators) (LN ₂ Cooled Preamps) (Wideband I-F)
BROADCAST DISTRIBUTION (Point-to-Multi-Point)		SR&T (Multi-Path Protection)	SYNCOM III (Triaxiality and Gravity Potential)	SR&T (RF Power Handling) (RFI Problems) (Heat Pipe Cooling)	ATS-III SR&T (Shaped Area Coverage)	SR&T (High Output TWTs)			ATS-III (12 KW Multi-Cavity Klystrons)	SYNCOM III	ATS-I ATS-III ATS-F (Small Stations)	ATS-III ATS-V (Preamps 30 GHz)
DIRECT BROADCAST SATELLITES (Point-to-Wide Area)	ATS-F	SR&T (Digital Multiple Access)	ATS-F&G (Low Thrust Jets) SR&T (Flexible Body Effects)	ATS-F (High Power Arrays) (Slip Rings)	ATS-F&G (30 Ft Deployable Array)	SR&T ATS-V (200 Watt TWT 12 GHz) (Multipacting High Power RF Components)	ATS-F	ATS-V ATS-III (SHF and Millimeter Wave Propagation)	SR&T ATS-F (Small and Transportable)	ATS-V	ATS-F SR&T (Small, Low Cost)	SR&T ATS-III ATS-F (100 Converters)
MOBILE Air Traffic Control (Surveillance Communication and Positioning)	Aircraft VHF SYNCOM III ATS-III (ARINC) ATS-F (Place)	ATS-III (Address Codes) ATS-IV SR&T (Coding and Modulation) (Error Correcting Codes)	ATS-F (Reaction Wheel) (Dual Spin) (0.1 Degree)	ATS-F (Two Axis Array Drive)	ATS-III ATS-F	SYNCOM III ATS-I ATS-III (On Board Processing) (40 Watt L Band)	ATS-I ATS-III ATS-F	SYNCOM (VHF) ATS-III (UHF) ATS-F (L-Band)	SYNCOM III ATS-I (ARINC) ATS-III (OPLE)	ATS-III ATS-F (Modems)	ATS-F ATS-I SR&T (Low Drag Designs)	ATS-F SR&T (Low Noise Detectors)

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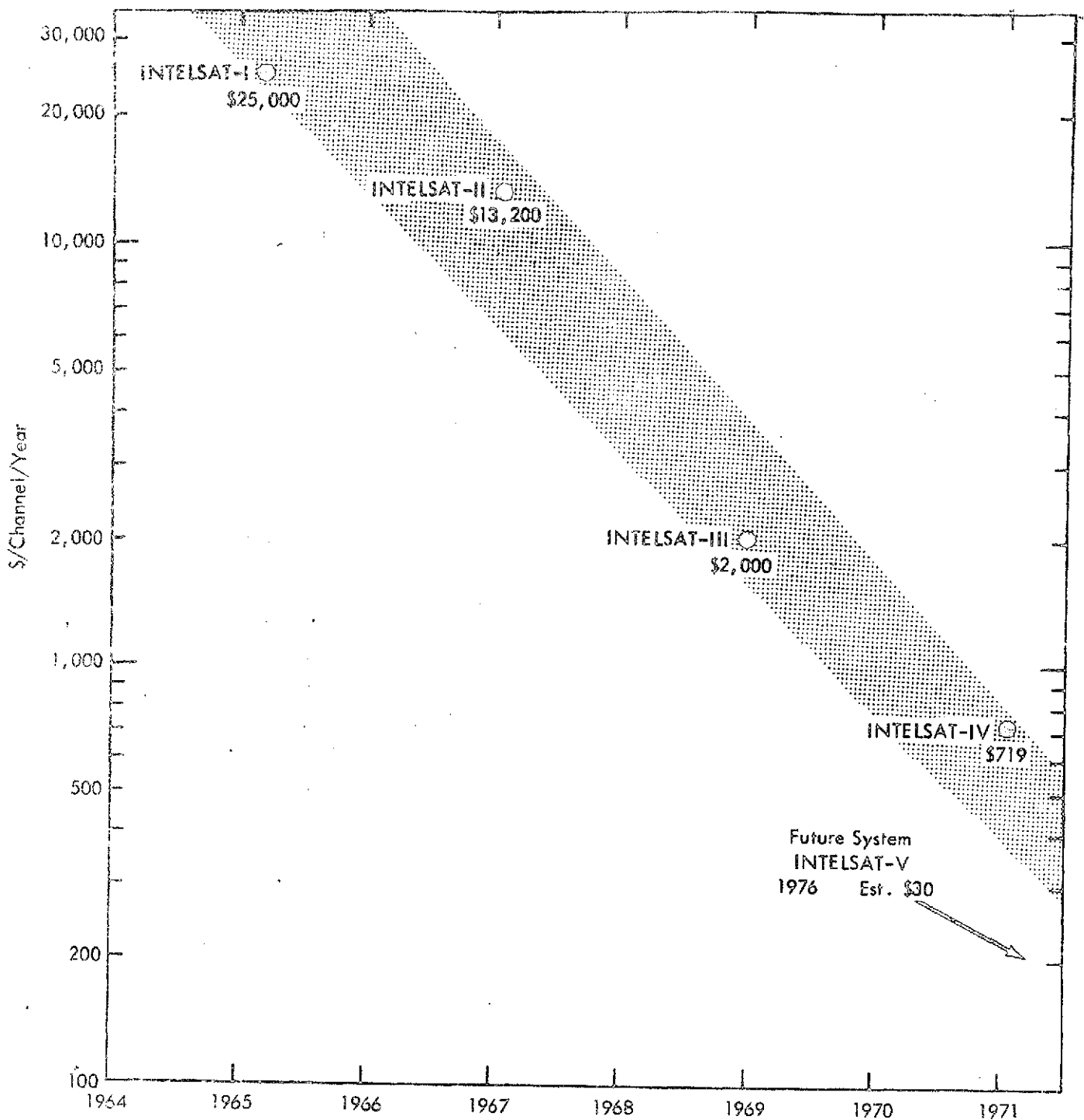
Alternative evaluation--There are almost always alternative, technical paths by which a requirement can be satisfied. NASA in its role as an R&D agency has provided the wherewithal for exploring the competitive advantages of alternatives. Tests of cryogenic masers versus cooled parametric amplifiers is a case in point.

Demonstration to acquire confidence--An important aspect of technological progress is the reduction of uncertainty; NASA flight programs have made many contributions of this type--through the accumulation of operating confidence and predictability. The replacement of earlier pressurized nitrogen and hydrogen peroxide station keeping systems by hydrazine systems depended largely upon acquiring confidence that poppet-valve control systems could be designed to operate trouble-free for several years. The demonstration that this was possible was accomplished on ATS programs. ATS is providing similar demonstrations of the capabilities and limitations in millimeter wave propagation. It should also be noted that demonstration of technical capability often permits the recognition that market demand exists. For example, many experts in 1962 indicated that there were not foreseeable demands for transoceanic television before 1980. AT&T's TELSTAR and NASA's RELAY demonstrated that a viable market demand existed. The ATS India TV experiment is in part designed to demonstrate the existence of another market area.

4. Economic impact of commercial communication satellite applications. Indicators of the present and future economic impact of the development of communications satellite technology and its application in the commercial sphere are provided in the MRI report. Figure 2 compares early estimates of the cost of communication by satellite with the dramatic cost declines actually experienced as the technology evolved. The reductions are striking. Similar cost declines have been experienced in earth station costs (see Figure 3).

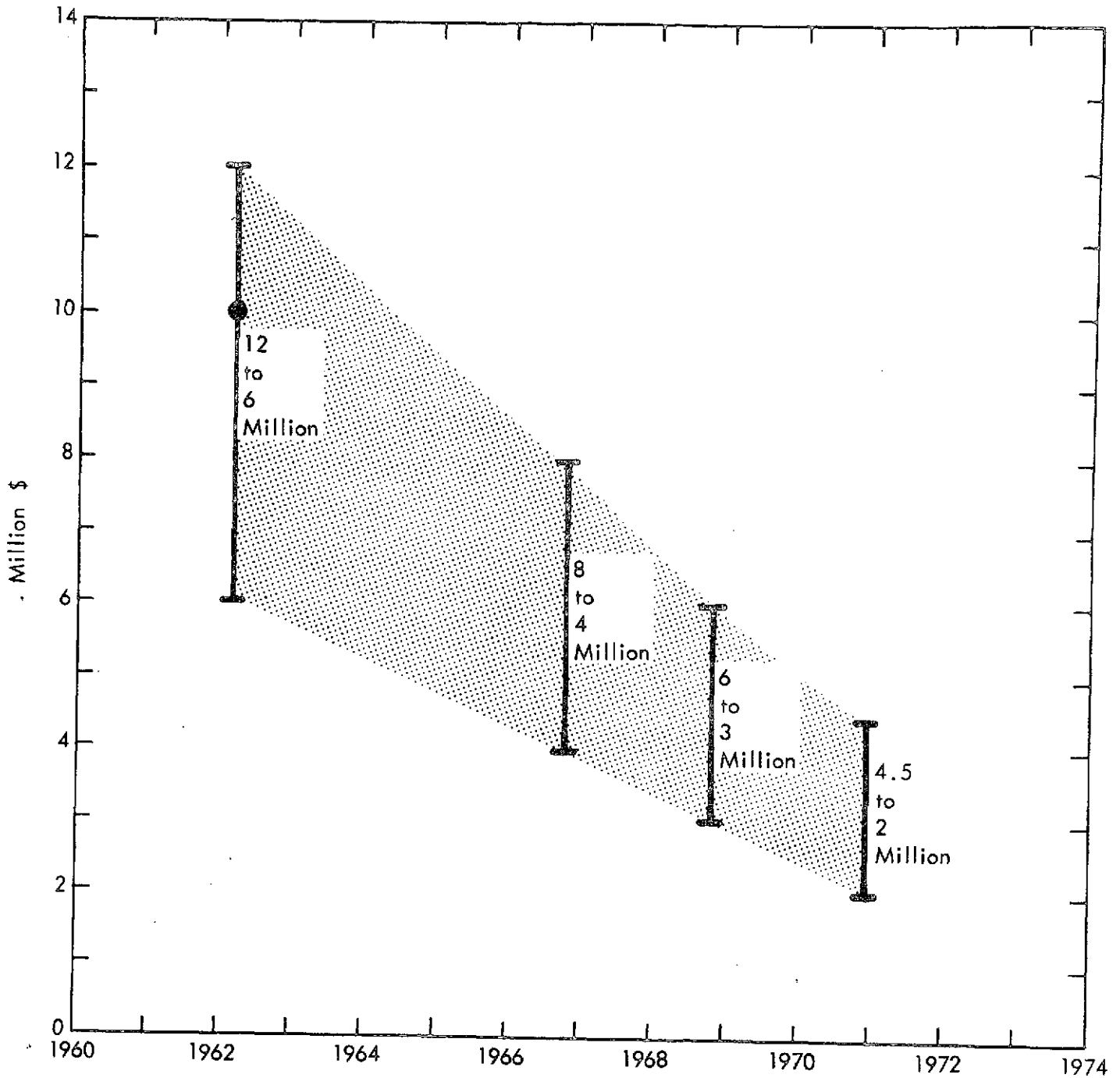
Because satellite communication offers both range of services and cost advantages over preexisting modes, growth in the International application has been dramatic. In its eight years of life prior to 1971 the Comsat Corporation has invested almost \$200 million in equipment and facilities; revenue grew from just over \$2 million to nearly \$70 million between 1965 and 1970. In addition by 1965 Intelsat had reduced its early per channel rental charges over 50 percent and an additional cut of the same magnitude is expected by the mid-1970's.

In spite of the rapid growth of the International application, the economic impact of domestic Broadcast Distribution will be much greater. The total overseas telephone and telegraph traffic is on the order of 50 million messages per year, while over 8 billion domestic long distance messages are carried annually. A total of eight applications for domestic satellite networks is pending before the FCC. The proposed initial investments range from about \$100 million to over one-quarter billion. Several



Source: Jack Eldred Cole, International Telecommunications Policy, Planning and Regulation. Doctoral Thesis, George Washington University, February 1971. Comsat Corporation, Pocket Guide to the Global Satellite System. December 1969 and Comsat Corporation Planning Document, January 1971.

Figure 2 - Dollars per Channel Year vs. Date of First Launch



Source: James B. Potts, Commercial Communication Satellite Earth Stations - Past, Present and Future. AIAA Paper 70-421. Presented at AIAA 3rd Communications Satellite Systems Conference, Los Angeles, April 6-8, 1970.
 "Satcom Earth Station Business Booming." Aviation Week, Vol. 90, No. 10, March 10, 1969, p. 264+.

Figure 3 - Basic Earth Station Costs

of the applicants have pledged to have their systems in full operation in less than 3 years after FCC approval. In Canada, a \$90 million domestic system will be in full operation by mid-1975. The bulk of the equipment is being supplied by U.S. firms.

The first commercial Mobile application will be an aeronautical satellite system providing communication links for transoceanic airline flights. Current expectations are for an investment in the \$125 million to \$150 million range for a two-ocean system for 1977.

5. Indirect economic impact on aerospace contractors. Most of the firms that performed substantial technical work in developing or experimenting with the NASA communications satellite systems were themselves affected--in a variety of ways--some organizations to a greater extent than others.

Conceivably the most significant finding from study of these contractors is simply that every firm interviewed indicated that their performance of space communications work had produced some residual economic effect. Not all effects were easily identifiable, but the challenge of high technology and the response by the company was stated to have influenced the firm or "left its characteristic mark."

The lasting consequences identified, fell broadly into three classes or types of influences:

a. Internal effects: Some firms modified their processes and procedures, the internal structure of the division, the ways they operated, their management systems, tighter quality control; or perhaps introduced new procurement policies or more efficient production methods. Economic effects from these internal changes are usually known as efficiency or increased productivity.

b. Direct commercialization: The majority of firms studied found ways to utilize the knowledge, expertise, and product capabilities that were augmented through NASA satellite work to establish or to strengthen their position in supplying the needs of commercial satellite systems. Early leaders, having demonstrated experience, became qualified suppliers partly by virtue of the "grandfather clause." However, much more was involved than a simple decision to sell satellite systems to another customer. Procedural as well as technological changes are also required as part of the changeover effort needed to sell to new markets or to commercial users having non-NASA requirements. But all contractors interviewed felt that the economic rewards derived from switching over to commercial sales were worth the efforts.

c. Transfer to non-space, non-satellite markets: Other firms utilized new knowledge, experience, and heightened perception of changing market needs, to transfer emerging or developed skills into new, non-space markets. New ventures, new services, non-governmental markets needing similar skills, and most of what has traditionally been called "spin-off" was found in this category of company effects. The economic effects are hardest to trace here. Seldom was there a direct one-to-one transfer; more commonly the transfer was feasible only because the contract suddenly perceived that a need, a technology and a market were approaching conjunction.

The major ways by which change affects progressive firms, and some of the points at which technical challenge and management response can induce innovations that lead to economic gains is shown schematically in Figure 4.

Technical change does not occur spontaneously; people have to make it happen. The "internalized costs" of innovation are not trivial. These costs include:

- (1) The cost of acquiring new knowledge--about market needs, about external situations, and about the availability of new technology.
- (2) The cost of learning to apply this new knowledge to the satisfaction of economic wants--education and training of production and marketing personnel; feasibility demonstrations and trial marketing.
- (3) The "changeover" costs (obsolescence and sunk-costs) of abandoning old ways and adopting new ways of performing the firm's economic function.

Recent scholarly studies of innovation have unmistakably shown that the force that induces industrial innovation is the economic pull of the marketplace, not primarily the forward thrust of new technology. The costs and barriers that impede the adoption of new technology (such as those cited above), are never easy to surmount. Within large organizations possessing considerable inertia, powerful forces are necessary for the successful introduction of any innovation.

Yet the fact is that innovation does occur, regularly--in both large and small companies. Firms do learn, adopt new techniques, improve designs and enter new markets--because technical change and innovation offers handsome economic benefits. A number of specific examples of this economic force at work were found during the survey of sample contractors.

SOURCES AND TYPES OF TECHNOLOGICAL OR ECONOMIC INNOVATION

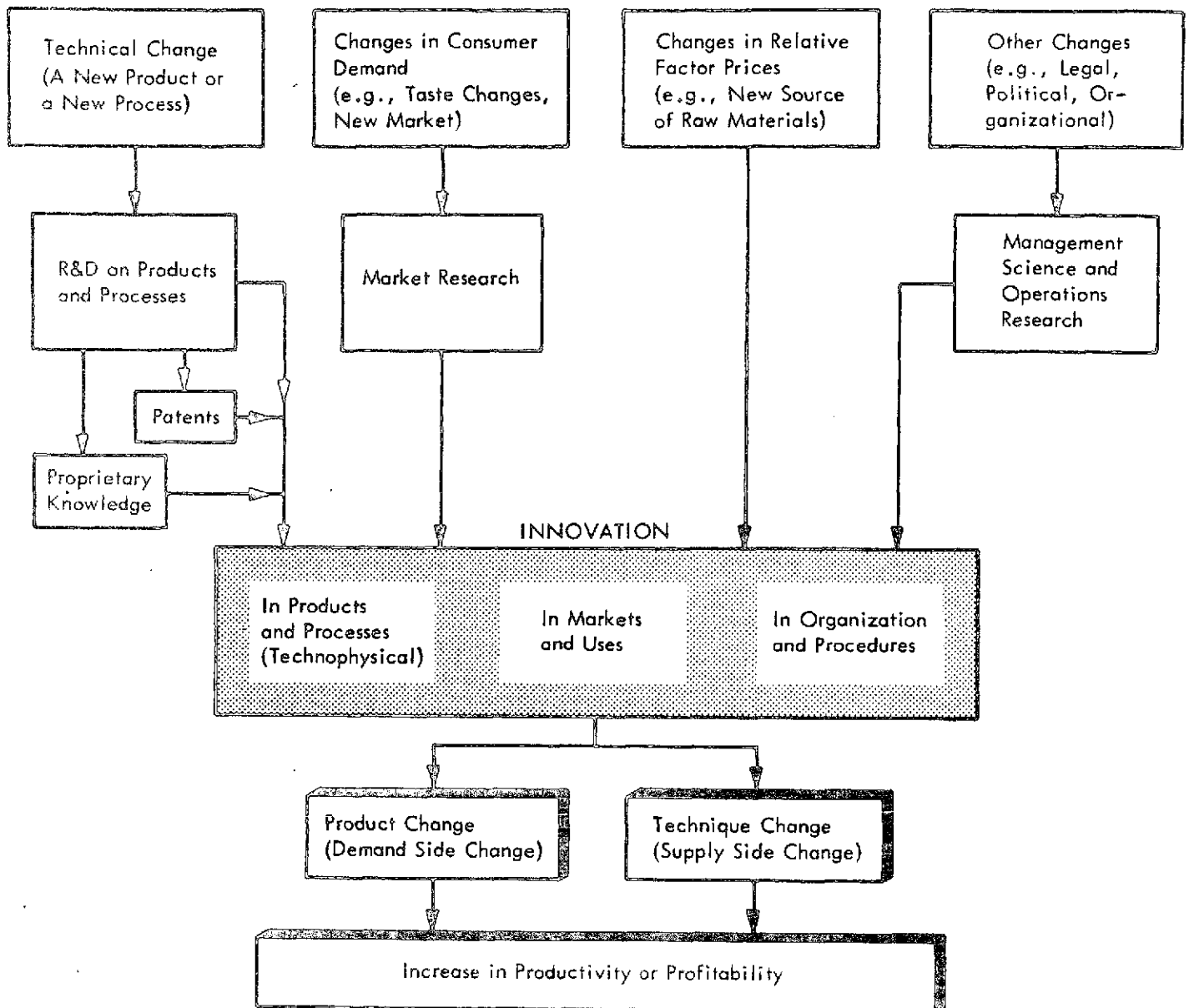


Figure 4

Participation in technically demanding and rapidly developing fields such as the early communication satellites and ground systems, can provide inputs, or act as "forcing functions" at several different points throughout this process as shown in Figure 4. Many of the firms interviewed in this study believed that their participation in space work had influenced one or more of these determinants of productivity or profitability.

Typical examples of how the various companies were affected can best illustrate the consequences of having worked on the communications satellite program. Undoubtedly, further investigation would have uncovered other interactions and, in fact, this list is far from complete, but it typifies the paths to economic gains within some of the firms.

Hughes Aircraft expanded its technological applications abilities into the commercial satellite area by becoming the principal spacecraft supplier to Comsat-Intelsat of the INTELSAT I, II, and IV devices. The old "Fire Control Department," has grown to a space division employing up to 4,000 people. Hughes further strengthened its position in commercial systems when it became the prime supplier of the ANIK satellites for the Canadian system. Hughes is one of the eight contenders for a domestic broadcast system. In a joint effort with General Telephone and Electronics, it proposes to supply the satellites for TV, telephone and other commercial communication links. Hughes also proposes to utilize these satellites as a means for distributing CATV signals to communities across the nation. The aggregate volume of Hughes commercial business springing from the SYNCOM success tops \$300 million.

Watkins-Johnson, a firm with outstanding capabilities in the conventional microwave tube field prior to their NASA involvement, applied technology gleaned from their experience with space qualified traveling wave tubes to their commercial line of devices. By successfully designing a tube compatible with the rigors of space, they were able to further expand their capability into ground based devices, and manufacture tubes with lifetimes far exceeding any prior units. Simultaneously, Watkins-Johnson improved their production expertise in other areas of tube manufacturing. As a further consequence of this NASA work, Watkins-Johnson became a recognized supplier of tubes for space use, and presently ranks as the number two supplier of space TWT amplifiers throughout the world.

Westinghouse Defense and Space Division does business almost entirely with government agencies. In theory, Westinghouse should experience only internal effects--no commercial products, no non-federal markets. Such is not the case, however. The division actively promotes commercial application of gravity-gradient boom devices and color enhancement techniques for TV. Their burn resistant S.E.C. Videcon tube has been an unqualified

commercial success. Among internal changes, Westinghouse management has adopted a program of planned employee rotation from other groups, into the space experiment packaging and integration group, for the explicit purpose of disseminating applicable technology.

Ampex provides a classic example of how a company met a NASA requirement for product standardization and extended the technique to their commercial manufacturing effort. After exploring and adopting methods of standardizing production, applying numerical controlled machining techniques, and modernizing their documentation and traceability in the manufacture of tape mechanisms for space, the practicality of transferring these solutions to commercial systems became apparent. The results were improved tape mechanisms for the many industrial and commercial users of their equipment, at prices substantially lower than had previously been possible. Higher performance standards at reduced cost, in turn, helped to further establish the Ampex position as a leader in sophisticated instrumentation recorders.

TRW Systems exemplifies how technology developed during a decade of satellite work can, with imaginative adaptation on the part of the practitioners, be transferred to commercial areas. Real-time data acquisition, processing and interpretation techniques, so vital for scientific satellites, are being adapted to the solution of problems of electric power distribution demand and control. The firm foresees that they will soon be profitably using similar techniques for the petroleum industry in areas of geophysical exploration, production optimization, and distribution.

The preceding examples clearly demonstrate how work in the space program has had definite--and identifiable--economic impact on the companies cited. Moreover, examples simultaneously illustrate the process by which knowledge--in the form of techniques, basic developments in materials and components and general business management skills--gained through NASA sponsored work has been applied in private sector economic endeavors. These forms of impact are included in the total economic impact of technological progress which was the subject of Part I of this report. The following brief examples are further manifestations of the indirect impacts from space program involvement.

Company Internal Changes

* Hughes Aircraft developed its own in-house components reliability program to such an enviable point that they are now documenting and selling this expertise as a separate marketable entity.

* Rantec has proceeded to develop sophisticated computer-aided antenna design routines, added electron beam welding equipment and skills, become proficient in electro-forming, and specialized in hybrid component

packaging--all technologies that help to secure technological leadership in the production and sale of antenna feeds for government and commercial markets.

* Watkins-Johnson has developed designs and techniques that make possible long-life and impact resistant TWT's. Proprietary arts that make high performance tubes practical have been responsible in part for W-J's growth and expansion from \$3 million to \$40 million sales since 1962.

* Westinghouse found that electromagnetic interference reduction techniques perfected in the packaging of scientific experiments aboard satellites were readily applied to the solution of underwater research problems. Management, recognizing the economic benefits of such technology transfer, subsequently formalized the process by publishing regular company bulletins called "Electromagnetic Design Notes."

* Ampex has altered the basis of their Management Information and Control System, patterning the new procedures after NASA's "fly-on-time" philosophy, and PERT-cost controls. Simpler reporting and tighter controls have resulted in substantial savings.

* General Electric has elected to continue developing its position in high-power, high-performance satellites, rather than compete against pioneering firms in low performance satellite markets. While developing technology needed to hold a commanding lead for this emerging multi-million dollar market, the research work itself has paid its own way. "The net-cash flow has remained positive," said the manager of G.E.'s communications satellite programs.

* Ampex was able to justify introduction of mass production tooling, numerical control drills, matched plate die casting, and other cost reducing technology to cut the cost of instrumentation grade recorders substantially.

* Three firms have contributed to, and been affected by the voluntary industry-wide code format and recording standards promulgated under NASA aegis, which in turn have upgraded instrumentation performance and helped insure compatibility of equipment.

Direct Commercialization of Satellites

* General Electric has established a primary position in supplying modems and other equipment to interface between satellite ground stations and terrestrial communication links. Nearly 8% of the more than \$300 million terminal equipment was produced by G.E.

* Hughes has designed and produced most of the commercial satellites for Comsat and for Intelsat--Early Bird, INTELSAT II, INTELSAT IV. Direct hardware sales of \$142 million are presented through INTELSAT IV-A.

* Sylvania Electronic Systems---formed a new division called General Telephone Electronics International to supply the commercial satellite market. This division, currently employing 100 people, has furnished major portions of over 40 earth terminals.

* Hughes Aircraft is now producing Canada's domestic satellite "ANIK." Together with Hughes' Canadian associate, Northern Electric, Ltd., this contract will generate \$32 million plus performance incentives.

* Rantec has become a standard supplier of cassegrain feed systems for earth stations in many countries. Costs of ground stations have become considerably lower over the years.

* TRW Systems (who in 1963 acquired the pioneering Space Technology Laboratories) became the second source for commercial satellites, as the spacecraft prime contractor to Comsat for the INTELSAT III series. The eight commercial satellites represented \$57.6 million in sales.

* ITT has produced 40 ft, 85 ft, and 30 meter diameter antennas for use with INTELSATS II and III. Worldwide sales of ITT satellite and ground station commercial equipment total \$75 million to \$100 million.

* Sylvania Electric has transferred directly to commercial sales for eight satellites of the INTELSAT III series, the technology of mechanically despun antennas developed by Sylvania for NASA's ATS III. The satellite customer directed TRW, the spacecraft contractor, to procure this technology and associated equipment from Sylvania.

* General Dynamics work in R&RR systems is considered a great asset in two out of three proposed Air Traffic Control satellite systems. This development scheduled for trial flight in 1974 represents a market of several hundred million dollars.

* Electronic Communications Incorporated has developed one-man transportable field terminals to work with satellites.

* ITT's solid state UHF amplifiers have formed the basis for several of the latest communications satellite transponders.

* ECI's pioneering work with circularly polarized loop-vee antennas has led to extensive commercial work with ocean buoy data relay systems using satellite data collection. When ERTS and other data collection systems are implemented, many thousands of small antenna systems will be required.

Transfer to Non-Satellite, Non-Space Markets

* Hughes Aircraft: Venture into CATV systems. The market for CATV is growing more than 35% per year; and 1971 operating revenues of \$375 million were up 21% over 1970.

* Watkins-Johnson: Tube reliability permitted offering a 1-year unqualified warranty on traveling wave tubes used in commercial test equipment.

* Martin Marietta: Five spin-off firms established by employees formerly working on NASA ATS-V. These small businesses employ 44 people selling exotic components and services to commercial markets.

* Martin Marietta: Currently applying millimeter wave technology to terrestrial computer links for dedicated and time-share services.

* General Dynamics: Two successful commercial companies spawned: RF Communications, and Scientific Products, Inc.

* TRW Systems: Presently applying space data handling and reduction techniques to electric power load distribution, demand and control to eliminate "brown-outs." TRW states that they hope to capture a fair share of this market, judged to average \$100 million per year over the next 6 years.

* Martin Orlando is applying satellite switching and systems techniques to the optimization of post office mail handling problems; and also to the improvement of airport design layout, efficient handling of baggage and passengers, as well as air traffic safety control.

* Watkins-Johnson has adapted techniques for rugged tube production to enter a new field--that of portable, lightweight (6 pounds total unit) industrial X-ray inspection equipment.

* Martin Marietta, having perfected techniques for producing large yttrium aluminum garnets for millimeter wave work, is seriously contemplating entry into the synthetic diamond market--which has already attracted other aerospace firms such as Litton Industries and General Electric. Synthetic diamonds currently enjoy annual sales of \$12 million and experts forecast growth at the rate of 15% per year for the next 5 years.

PART III

CASE STUDY--KNOWLEDGE ADDITIONS AND EARTH LINKS FROM SPACE CREW SYSTEMS

A continuing stream of scientific and technological knowledge is an essential part of the process of public and private "want satisfaction" through applied technology. The technology application process examined in Part II is dependent upon a continual replenishment, extension, and refinement of an underlying knowledge reservoir. Since knowledge is a necessary precondition to the achievement of any goal or the solution of any problem, it is appropriate to ask: What sort of knowledge have we obtained from our investment in the space program and what relevance does it have for us down here? Part III is addressed to these twin questions.

A. THE KNOWLEDGE BANK

What does the knowledge bank consist of? In simplest terms, it is everything known to man. The bank can be stratified in a number of ways, one of which is a spectrum ranging from knowledge on basic phenomena to manufacturing know-how. Also embodied in the knowledge bank are many grades of accuracy or precision. As the problems we address become more complex, additions and refinements to the knowledge bank are essential. Another characteristic of the knowledge bank is that the information in it usually contributes to the solution of problems beyond those visualized by the original developer. Thus, the ultimate utility of any piece of know-how cannot be assessed at the time of its generation.

What are the mechanisms by which we add to and refine the knowledge bank? There are many. At one extreme, we have basic research; at the other we have the individual innovator faced with a very specific problem. Somewhere in between the extremes is so-called mission-oriented research, of which the space program is an example. Since mission-oriented R&D programs typically stretch some aspect of the state of knowledge and ultimately culminate in hardware, they often make broad contributions to the knowledge bank--in the basic and applied sciences, in several engineering fields, in manufacturing processes, in analytical techniques, and so on.

We chose to examine the contributions expected of mission-oriented R&D by a case study of those aspects of the manned space program directly related to human life support and work performance in space.

B. WHY STUDY CREW SUPPORT

On the surface, about the last way one might expect to generate useful down-to-earth knowledge would be from putting man into space. It is obvious to all that about every characteristic of the space environment is different than its counterpart down here on earth. Space is a hostile, uninhabitable environment. Man must be encapsulated (spacecraft or space suit). The exterior of the capsule must protect against space hazards. The inside must provide an environment suitable for life. Performing the simplest earthly tasks and functions during space flight requires elaborate planning and provisioning.

Providing acceptable solutions to everyday human performance under the strict and unforgiving discipline imposed by space flight conditions posed a tough technical challenge. But, critically important from the rational viewpoint, the very process of reexamining man's needs in these new lights, required new inputs and provided a sharp stimulus to better understanding of ordinary functions--like breathing or sweating, or bending at the waist.

To design life support systems for space, the engineers must have comprehensive guidance on the interactions between man and his environment. Because man is complex, knowledge on these interactions was incomplete at the time that the space program was launched. It has been difficult, given our knowledge base, to specify and provide some form of optimal environment here on earth. Real difficulties begin, however, when the optimum environment is not attainable. At the present time, it just is not possible to take into space all of the things that man is used to here on earth. Thus, the task becomes one of deciding what to take along. This requires that physiologists and related medical specialists be able to state as clearly as possible the penalties associated with departing from the optimum environmental state.

Much of the information necessary to make the penalty assessments was not available. Therefore, scientists had to undertake research. Physiologists and others had to become much more precise in their understanding of human life requirements.

The research undertaken made it possible to specify the life support requirements for different space missions. These, in turn, provided guidance to the design engineers charged with the design of equipment and systems which would meet the requirements. In many instances, the knowledge available to engineers in their own fields was inadequate for the task at hand--in much the same way that physiologists' knowledge of requirements was lacking. Research was supported to develop data and extend the available engineering knowledge.

Given the design, it was then necessary to manufacture and test the equipment for the space flight. In many instances new knowledge was necessary in this area, too -- new materials were required, tolerances were smaller, reliability had to be higher, and so on.

Thus, a case study of knowledge contributions from the crew support aspect of the manned space program seemed in order.

C. RESEARCH PROCEDURE

The basic research technique employed in the study was personal interviews with NASA contractor and NASA laboratory personnel. Selection of interviewees was made following a series of computerized searches of the NASA RECON information system. These searches disclosed that in excess of 160 contracts and supporting studies had been performed within the crew support area. Clearly, all these participants could not be contacted within the resources allocated to this study.

Industrial contracts for system fabrication were given preference over academic grants and considerable weight was given those groups involved in the development of equipment for extravehicular activities. Nine company groups, the Air Force School of Aviation Medicine and two NASA laboratories were selected for personal interview.

The interview procedure was quite simple. Several participants in crew systems research and development at each firm or lab were asked:

* What did you have to learn in order to do your part of the manned space program, i.e., what was known and unknown when you began?

* What sort of solutions did you develop and apply?

* How--if any way--does what you learned or what you did relate to earthly problems?

During the course of the interviews, several additional organizations that had made key contributions to the crew support effort were identified. The facts surrounding the contributions of 14 were subsequently obtained via telephone and literature review.

The final step in the research program was to synthesize the findings of the individual interviews and develop an organized presentation thereof.

D. THE FINDINGS

In the process of devising systems needed for space crew support and extravehicular activity, a surprisingly large amount of new and extended knowledge was acquired. These contributions to available knowledge span a wide range--from understanding of basic phenomena to specific processes and devices.

Even though this knowledge was derived from satisfying specific space mission requirements considerably removed from normal earthly problems, the knowledge gained appears relevant to many current domestic concerns. The ultimate impact, while impossible to specify at this time, may be widespread and significant.

Ten to twelve illustrations of new or improved knowledge were noted in each hour to hour and one-half interview, and most of the knowledge gained had some relationship to needs here on earth. In total, Part III of this report presents over 130 illustrations--identified during our limited number of interviews--wherein knowledge additions are traceable to the crew systems effort of the space program. Part III is arranged in terms of nine requirements which have to be met to maintain man alive and productive in space. Each space requirement and the work undertaken toward its satisfaction is briefly described. Then, capsule summaries of each knowledge contribution illustration--traceable to a requirement--are provided, and the actual and potential linkages to earthly problem satisfaction are indicated.

The nine space requirements, the number of knowledge addition illustrations attributable to each, and the number of knowledge contributions contained in the illustrations are:

<u>Space Requirement</u>	<u>Illustrations</u>	<u>Knowledge Contributions</u>
Supply Breathable ATMOSPHERE FOR SPACE	13	48
Metabolic CARBON DIOXIDE--REMOVAL	9	40
RECYCLING	13	40
CONTAMINANT CONTROL AND REMOVAL	15	54
Maintain THERMAL BALANCE	24	111
Space HAZARDS--DECOMPRESSION, RADIATION, METEORITES AND FIRE AND BLAST	17	75
Provide Adequate LIGHT AND VISION	17	70
Provide MOBILITY AND WORK CAPABILITY	23	79
Provide Adequate HABITABILITY	<u>6</u>	<u>14</u>
Total	137	531

The knowledge contributions contained in the illustrations span the full range of the knowledge bank: from better understanding of basic phenomena, through design and engineering, through materials and production processes to individual products and markets. Table 4 indicates the contributions in 11 categories.

Many illustrations embody more than one category of contribution. In fact, the average is about four per illustration. For example, a typical illustration might involve the intensive study of an incompletely understood phenomenon, together with an extension of our knowledge into a totally new regime, and the development of improved fabrication and processing techniques.

In general, the contributions occur most frequently in the design and engineering portion of the spectrum. Otherwise, there is a slight weighting toward the phenomenon end of the scale, with immediately applicable production and product contributions being slightly less frequently encountered. Overall the distribution of contributions follows the pattern which would be expected given the challenging nature of the space requirements.

Similarly, the significance of the contributions is representative of the nature of scientific and technological progress. About 10 percent represent step changes in our knowledge, i.e., those which effectively changed the state of the art or established a new standard in a field. Most of the contributions were incremental advances (44 percent) in either scientific understanding or technology, or were consolidation of technology (46 percent). The latter being instances where several existing concepts were consolidated and integrated to achieve the desired end.

The utility of the knowledge is not confined to space but is also relevant to a number of down-to-earth issues. Table 5 summarizes the linkage of the contributions to 13 categories of earth utility. In total almost 200 links were identified. All may not come to pass, instead other less obvious linkages may emerge. Predicting areas of greatest utility for given pieces of new knowledge has been subject to significant oversights throughout history. Thus, the linkages on Table 5 are those which seem most clear to the authors; they are offered only as indications of ultimate impact. But, the breadth of actual and potential impact is such that the linkage to earthly problem solution--of the space-induced knowledge additions--is apparent.

Ten typical illustrations are presented in the balance of this summary volume to provide a more concrete "feel" for the types of contributions and linkages encountered in our survey.

TABLE IV

		Space Requirements							
		Atmosphere	CO ₂ Removal	CO ₂ Recycle	Contaminants	Thermal Balance	Space Hazards	Light and Vision	Mobility
CONTRIBUTION CATEGORIES									
Newly Recognized Phenomena	2	1	2	1	4	4	1	1	1
Little Understood Phenomena	9	8	5	9	13	9	7	13	2
Baseline Data	3	6	2	5	9	6	3	4	1
New Regimes	4	3	9	10	12	15	13	16	4
Research and Measurement Techniques	1	6	5	10	14	10	13	15	4
Materials	3	3	2	6	10	11	8	8	1
Design Refinement	7	6	2	5	19	3	6	10	1
Fabrication and Processing	8	1	4	-	8	5	6	8	-
Manufacturing Operations Control	3	3	6	3	8	1	4	-	-
Products	7	2	3	4	13	8	8	4	-
Market	1	1	-	1	1	3	1	-	-
Total		48	40	40	54	111	75	79	14

TABLE V

		Space Requirements								
		Atmosphere	CO ₂ Removal	CO ₂ Recycle	Contaminants	Thermal Balance	Space Hazards	Light and Vision	Mobility	Habitability
EARTH LINKS										
Health and Medicine										
Diagnosis	1	-	2	1	-	-	1	-	-	
Treatment/Therapy	3	-	-	-	4	4	-	6	-	
Surgery	1	-	-	-	1	2	-	1	-	
Prevention	1	1	-	3	1	2	-	-	-	
Food and Agriculture										
Feeding	2	-	-	-	-	-	-	-	-	
Construction	-	-	-	-	-	3	1	2	1	
Industry										
Processes	5	1	4	3	2	3	5	1	-	
Design and Engineering	2	1	1	1	3	-	-	-	-	
Quality Control and Safety	1	2	-	4	8	1	4	7	1	
Transportation										
Energy	3	2	-	1	1	5	10	1	-	
Energy										
Environment	2	-	-	-	5	-	-	-	-	
Emergency Services										
Emergency Services	2	1	-	11	-	-	-	-	-	
Leisure and Recreation										
Leisure and Recreation	1	-	-	-	-	-	2	2	-	
Education and Training										
Education and Training	2	-	-	-	3	1	2	2	-	
Households										
Households	-	-	-	-	-	-	3	-	-	
Research										
Research	1	-	-	-	2	1	-	-	1	
Total		30	9	13	25	35	26	29	23	3

FLOW
RESISTANCE
REDUCED

Capability to design and construct heat exchanger cores requiring minimum air flow across the fins and low flow resistance across the exchanger has been (greatly) extended.

Earth link--Achieving highly efficient transfer of heat requires that the air flowing over the fins be continuously mixed. The achievement of designs and equipments which induce precisely correct air turbulence while minimizing flow friction required several advances. The effect is the present existence of heat exchange units which are very efficient, minimize noise, and have lower blower power requirements, i.e., smaller, quieter air-conditioners.

THERMAL BALANCE

HEAT
PIPES

To maintain space suit thermal balance, heat pipes have been adapted to transmit metabolic heat through the pressure garment and into space. Several innovations were achieved: (a) A controllable heat pipe or "Thermal Switch" was created, permitting heat flow to be modulated by a throttling valve, or if desired, operated in an on-off fashion. (b) The first flexible heat pipes were developed. Flexible heat pipes maintain contact with the skin of the astronaut, yet permit normal body movement within space suits (both "hard" suits, and the more common fabric pressure suits). (c) Improved heat pipe materials, wicks, working fluids and construction techniques were developed and tested. Techniques were devised to prevent freeze-up, and to make heat pipes which were inherently capable of re-starting after solidification of the transfer fluid.

Earth link--TRW Systems Division, which developed heat pipes suitable for cooling space suits, has since granted licenses for use of this technology for industrial process furnaces. A major use of these furnaces will be the production of semi-conductors (which require extremely uniform heat treatment). Other heat pipe applications range from the processing of jet aircraft turbine blades to cooling nuclear reactions. A manufacturer in New Mexico has acquired rights to market a household "cooking-pin." This culinary aid uses the heat pipe principle to transfer oven heat to the center of a roast or turkey, reducing cooking time by one-half.

TRW Systems Division has also built an environmental test chamber at the Manned Spacecraft Center, which is possibly the world's largest heat pipe. This chamber automatically maintains completely uniform temperatures throughout the 45 ft long, 14 ft cylindrical room.

CONTAMINANT CONTROL AND REMOVAL

IMPROVED VACUUM EVAPORATORS

Compact distillation equipment has been developed that is capable of long term operation without loss of efficiency or need for maintenance. Two techniques, vapor compression distillation and vacuum flash distillation, each offer several advantages for processing heat-sensitive materials.

Fundamental studies in vacuum evaporation were required. Available knowledge on water jet injection theory and design data were judged inadequate to insure the achievement of the ultrafine, low velocity droplets necessary for highly efficient flash distillation units. Fuel injection theory developed for rocket engines was adapted to water atomization.

Earth link--Although developed by NASA to purify water, the knowledge adds to the technological base underlying a number of commercial processes which remove water from heat-sensitive products. Spray drying in vacuum chambers is the process employed in the production of "instant" food products, e.g., instant coffee and soups, dry nonfat milk, etc.

CONTAMINANT CONTROL AND REMOVAL

COORDIN- ATION TESTER

A compact coordination tester has been developed to determine the effect of atmospheric contaminants on astronaut performance. This device permits measurements of hand-eye coordination in several tracking and pursuit tasks, and the influence of toxic materials and fatigue can be determined.

Earth link--This Langley device has been demonstrated to Driver Education officials in California and was found to be suitable for testing driver coordination. The Environmental Protection Agency has found the tester useful for measuring effects of air pollutants, carbon dioxide and monoxide on driver performance. The degree to which alcohol degrades driver ability can also be tested.

**OPTICAL
GRADE
POLY-
CARBONATE
SHEET**

Optical quality, premium grade polycarbonate sheet plastic was developed and produced initially for the Apollo helmet. Standards and quality control procedures plus contamination free processing facilities and techniques (clean room procedures) necessary to upgrade extruded Lexan sheet were developed. The improved plastic has closely predictable thermal processing characteristics and enhanced solvent resistance, together with superior optical properties. The manufacturer states that material of this quality would not have been developed without the helmet requirements.

Earth link--The improvements in production procedures and material properties have contributed to the production know-how applied to a variety of optical polycarbonate applications. Safety, riot control and motorcycle helmet faceplates, aircraft windows or canopies, plus screens around hockey rinks are examples.

**EYE MOTION
MEASUREMENT**

A NASA designed oculometer that measures eye movements in carrying out search and discrimination tasks makes it possible to determine the speed and efficiency with which the eyes process information within the visual field. Persons engaged in activities requiring vigilance and highly developed discrimination can be aided by training based on oculometer data.

Earth link--Conventional oculometers operate by shining points of light on the eyes which are photographed to provide eye movement tracks while the subject is performing visual tasks. The new oculometer is nonintrusive because it uses near infrared light. In addition, it provides real time eye movement tracings which are displayed on a screen. Thus, an instructor can coach the pupil in improving eye use. The extent to which the person under test can or cannot follow a particular eye movement procedure provides a means of testing concentration and alertness. The oculometer has utility in training air traffic controllers and quality control inspectors, in reading analysis and psychological testing, and for studying the early development of the oculometer system in children.

FLURO-
ELASTOMERS

NASA's search for elastomers that would not burn in oxygen prompted Minnesota Mining and Manufacturing Company to submit samples of several new experimental rubbers--all based on copolymers of hexafluoropropene vinylidene fluoride. All samples exhibited good physical properties, but burned under spacecraft conditions. The 3M Company modified their products to obtain an elastomer tailored to Apollo requirements. Fluorel rubbers resulted. Viton, another fluoro-substituted rubber was similarly modified to meet space requirements.

Earth link--These elastomers have the capability for use in a variety of oxygen-rich environments. Anesthesia hoses and masks from the material would reduce operating room flammability risks, for example. The material is being used in the interior decorative panels on commercial aircraft to reduce the possibility of fire spread and smoke production. They are also finding use as an upholstery coating in aircraft.

ATMOSPHERE FOR SPACE

STABLE
OXYGEN
SENSORS

New and improved types of oxygen measuring instruments were developed because of the importance of monitoring oxygen concentration in space.

The space requirement encouraged the development of miniature stable polarographic oxygen sensors that need only infrequent calibration, and are rugged and inexpensive enough for rather wide use.

Earth link--Measurement of oxygen content in air and liquids has traditionally been a cumbersome and sensitive operation. Winkler titration and gas chromatographic techniques have been the most common procedures. Both are laboratory procedures. Polarographic oxygen sensors have been employed but electrodes previously available were unstable and required recalibration for each use. The new membrane type polarographic sensors are extremely stable and permit direct readings of oxygen content. They are being used in water pollution and oceanographic studies, for measuring dissolved oxygen and as pocket size hypoxia warning devices for mine safety.

**ELECTROLYTIC
OXYGEN
SUPPLY**

Water electrolysis systems capable of furnishing crew oxygen have been developed and operated for more than 10,000 hours to demonstrate reliability. The vapor phase water feed system designed to permit zero gravity operation, while not needed for that purpose when operated on earth, is largely responsible for the long term, troublefree operation of these units. The operating life of previous electrolysis units was typically limited to 1,000 hours.

Earth link--At present there are a number of situations which require that oxygen be stored at high pressure. This is an inherently hazardous procedure. If impurities in minute quantities (dirt, metal chips, or organic contaminants) are present in the system during filling, an oxygen fire may occur, often resulting in rupture of the pressure system and rapid spread of the fire. In spite of elaborate safety procedures there have been several major commercial aircraft fires of this sort (all on the ground).

This electrolysis system is being tested for military aircraft, and is under consideration to replace high pressure oxygen for emergency use by commercial airline crews. The system provides oxygen on demand and does not require storage.

Water electrolysis is also being investigated as a source of oxygen for newborn infants. To prevent eye damage the amount of oxygen supplied to the incubator or isolette must be precisely controlled. Present practice is to measure flow rates of the oxygen being delivered from storage tanks. Greater precision can be obtained by water electrolysis generation of oxygen, because oxygen production is directly related to the supply of electrical current to the unit. A related instance in which electrolysis systems may prove apropos is in the supply of supplemental oxygen to persons suffering from chronic emphysema or asthmatic conditions.

DIRECT BODY
CALORIMETRY

Direct, whole body calorimetry can now be performed conveniently and accurately on a dynamic basis, by recording heat transmitted to liquid cooling garments. Previous techniques were indirect or restricted in the extent of human activity permitted, or had slow response rates which precluded study of thermal transients.

Earth link--Prior to the application of the liquid cooled garment to dynamic calorimetry studies, it was necessary to use secondary measures of metabolic heat production (e.g., oxygen consumption) or rigid calorimeter chambers. Now direct metabolic heat measurements are possible, the equipment has considerable flexibility and places few constraints on the study subject. Direct calorimetry is being employed on a number of research topics, including: physiological research on basic body homeothermic and metabolic processes; medical research on fever and antipyretic treatments, on diet--such as the specific dynamic actions of various classes of nutrients; on metabolic disorders--such as thyroid function; on the various types of shock and the physiological processes involved, and on heat exhaustion and sunstroke investigation; in industrial hygiene for the study of workers in hot and cold environments for the establishments of work standards and practices; and even in the study of athletic stamina and endurance.

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The findings of this study indicate that the long-term economic benefits of the space program are much more profound than superficial examinations would indicate, and that the importance of technological progress to national well-being must not be ignored. However, much remains to be learned about the specifics of how technology interacts with the economy. The investigations reported upon in this five-volume work were performed within the current state of the art. There is a need to extend and refine our knowledge on many aspects of advancing technology and its economic and social impacts. The present researchers hope that this study will encourage others to seek better understanding of the processes involved and more precise answers to the questions we addressed.

APPENDIX B

to the

STATEMENT OF

Clare F. Farley

Deputy Assistant Administrator for
Technology Utilization

Example of Transfer to the Public Sector

URINE-MEASUREMENT SYSTEM FOR POSTOPERATIVE FLUID MAINTENANCE

An aerospace-derived system to improve the postoperative measurement and maintenance of body fluid levels is now being clinically tested at the Hahnemann Hospital in Philadelphia. Based upon the urine-transport system developed for the NASA Biosatellite program at NASA Headquarters, the new equipment will accurately record urine volume output versus time. The output of this system can be used to control the rate at which additional fluids are administered to the patient.

One of the essential indicators of a postoperative patient's condition is his fluid-intake-output record. Additional fluids must be administered to a patient passing a large amount of urine in order to maintain a proper electrolyte balance. Excessive retention of urine or unusually high rates of urine output are indicators of patient difficulty. The present practice is for a nurse to manually record the amount of urine in a calibrated container at specified intervals. This procedure is not completely satisfactory. Patients often slip into electrolyte imbalance, with scant note made of their increased urine output.

The urine-transport system originally developed for the monkeys in the Biosatellite program provided a solid basis for further development leading to a more precise and reliable clinical urine-measurement system.

The new system works this way: The patient's urine is collected in a holding tank and accurately measured in small increments. It is then pumped into an analysis bag so that it may either be collected for further laboratory tests or discarded. The system provides a direct digital indication of the patient's urine output. Connected to a monitoring computer, the system will

provide information on the patient's rate of fluid output and will immediately inform nursing personnel of unusual conditions. Through computer hookup, it can also be used to control the rate at which additional fluids are administered to the patient, permitting precise maintenance of body-fluids content.

A less sophisticated version of this device has been in clinical use at the University of Alabama for more than a year. Used to maintain the fluid levels of cardiac patients during the first 24 hours after surgery, it has proved useful in patient care. Maintenance of constant fluid levels places less stress on the patient than the depletion-restoration cycle normally encountered and less time is required of medical personnel.

Two prototypes of the new Biosatellite-based system were delivered for clinical trials to the Hahnemann Hospital in February 1972. The bacteriological evaluation was satisfactory and the systems were installed, one in a shock-trauma unit, the other in a post-surgical recovery area. Preliminary clinical trials uncovered some design difficulties which have since been corrected. Following successful demonstrations of these units, additional prototypes will be released for further clinical evaluation. The unit is being studied for commercial development and marketing by the General Electric Company.

DETECTION OF EYE TUMORS USING RADIATION PROBES

A semiconductor radiation detector developed by Solid State Radiation Inc. for NASA's Manned Spacecraft Center has been adapted as a probe for greater precision in the diagnosis of eye tumors. The Scott-White Clinic and Hospital originally posed the problem to the Southwest Research Institute's Biomedical Application Team.

The device--now commercially available--is being used by physicians to detect the beta-radiation emitted by radioisotopes which are administered intravenously to patients with suspected tumors that are either hidden from direct observation or are in such an early stage of development that they can not be detected by conventional means. Since tumor cells absorb radiation differently from normal tissue, detection of increased radioactive emissions can help determine the presence of a tumor.

Conventionally, physicians using the radiation-detection technique for diagnosis, have to insert a dime-sized Geiger counter probe between the patients eyeball and eye socket. The probe is excessively large and it lacks sufficient directionality to provide precise information on whether increased levels of radiation indicate a tumor or simply an increased blood flow in one of the eye muscles.

In contrast, the adapted NASA radiation detector is small enough to put in a 2-millimeter diameter probe. Mounted at the tip of a catheter, it can be inserted behind the eye with minimum trauma. The probe which incorporates a thick-film preamplifier next to the detector has a signal-to-noise ratio that is compatible with recording equipment. It is highly sensitive and produces a realistic measurement of the spatial and energy distributions of beta-radiation.

Using the device, doctors can determine more accurately the distribution of the isotope, making their diagnosis more specific. This could reduce false-positive tumor diagnoses and unnecessary eye surgery.

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IMPROVED PHOTOGRAPHIC SYSTEM FOR X-RAY DIAGNOSIS
OF TUMORS AND CARDIOVASCULAR PROBLEMS

NASA's Marshall Space Flight Center and Vanderbilt University have adapted a real-time neutron-radiography welding inspection system for use in rapid x-ray diagnosis of tumors and examination of cardiovascular flow. Image intensification, video-data processing and display and kinescope photographic recording systems have been added to extend the usefulness of the system.

The combined system will be used in Vanderbilt studies of children suffering from congenital heart disorders. The system will be put to work visualizing the site of the heart defect and measuring the amount of blood flow through anomalous channels. The information gained is expected to help doctors determine which patients should have operations and at what age.

The sensing system is based on proton-electron interchanges that are amplified in an image-intensifier tube. The tube's output can be fed directly to a high-resolution video display and data can be recorded on magnetic tapes or digital-disc recorders.

A particular advantage of the system is that since pictures can be made directly from the video system, a tenfold reduction in radiation dosage can be achieved. This is especially valuable in the diagnosis and treatment of children.

The techniques for high quality translation of video tape to motion picture film were also developed by NASA in early Saturn flight tests.

HYPERTENSION SCREENING DEVICE

A transducer developed at NASA's Goddard Space Flight Center has been used to externally record arterial-pulse pressure waves and has completed six months of successful clinical evaluation at the Washington, D.C. Veterans Administration Hospital. The special value of the NASA device is that it allows physicians to evaluate the functional status of the carotid arteries in atherosclerosis patients without having to insert monitoring catheter devices into their bodies.

The NASA-developed transducer is being used in a Hypertension Study at the Veterans Administration Hospital. The data acquired is used to determine the relative elasticity of each patient's carotid artery and the responsiveness of his circulatory system to various drug treatments. Field tests of the device are also under way at six other Veterans Administration Hospitals around the country.

The NASA device, which uses a Pitran displacement pressure transducer, has good high-sensitivity and low-frequency response. Although displacement-pressure measurements of the carotid artery do not replicate the pulse shape as can be done with an inserted catheter, the external measurements do convey clinically useful information. Permanent records can be made quickly and without penetration of the skin or discomfort to the patient.

Previous attempts to develop an external-displacement type pressure transducer had been unsuccessful because of mechanical design problems or extreme mechanical complexity resulting in high production cost. The simpler design of the NASA-developed transducer is expected to be much more reliable and much less costly to manufacture.

RAPID DETECTION OF BACTERIA IN BIOLOGICAL FLUIDS

Based on aerospace technology, originally developed at the Goddard Space Flight Center for use on the Viking mission to Mars, two devices which show considerable promise for speeding and automating the detection of bacteria in biological fluids are currently being tested at the Johns Hopkins Medical Center and the Washington, D.C. Veterans Administration Hospital. In less than 15 minutes, these new techniques can indicate the quantity of bacteria present in a body-fluid sample. Such analysis by conventional techniques usually takes 24 to 72 hours. The devices are each based on different approaches to this significant medical task.

One device is designed to detect ATP, a biochemical compound present in all living cells. In that system, the quantitative determination of bacteria is made by measuring light emitted in the reaction of the ATP in the bacteria with luciferase (an enzyme derived from fireflies). The reaction produces an observable flash of light.

The other device uses a technique based on changes that occur in the electrical potential of growth medium as the oxygen is consumed by growing bacteria. It also provides an immediate reading to the observer.

The two techniques and systems under study--both of which are automated to alert the laboratory workers to the presence of bacteria--offer important potential advantages to physicians. The devices could help determine not only the presence of infection in body fluids but also provide information on the patient's response to various kinds of medication.

Recently, a program has been started at Tufts University to use the ATP detection system to evaluate the effectiveness of various antibiotics against certain bacteria. It is expected that this system will allow a lab technician to rapidly determine not only the presence of bacteria in a biological fluid

sample but also help determine the antibiotic which most effectively destroys that bacteria.

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DIRECT VIEWING RADIOGRAPHY

Solid-state image amplifier panels originally developed for non-destructive testing of steel welds at NASA's Marshall Space Flight Center appear to have properties that make them appealing for clinical and diagnostic x-ray procedures in medicine.

A particular advantage of the panels is that their high sensitivity to x-ray allows reduction of radiation dosage. In fact, conventional fluorescent image amplifiers now being used require 50 times more radiation than the aerospace-derived solid-state panels. Also, the contrast range on the new screens is greater than that of currently-used devices. This could make certain kinds of interpretation and diagnosis much easier. Also, the new panels--which were originally developed for in-space inspection and checkout in an environment where room for film storage and development was not likely to be available--could be easily used by doctors in remote locations. This would make possible radiographic examination for fractures, internal organ damage and disease in settings where conventional equipment was not available.

NASA and the Tulane University School of Medicine are working together to evaluate the diagnostic utility of these aerospace solid-state image amplifiers.

DEVICES TO ASSIST TOTALLY PARALYZED PATIENTS

Patients paralyzed in all four limbs, multiple-amputee patients and patients with severe neurological disorders are almost totally dependent upon outside support. Their morale is markedly improved and the demands on patient-care personnel are greatly relieved by any device or procedure which enhances their self-sufficiency. NASA technology is aiding in the effort to produce such advances, after the Biomedical Application Team at Southwest Research Institute had recognized this as an urgent problem in rehabilitation medicine.

For example, paralyzed patients and amputees are now using a NASA-developed sight switch to control electrically-operated assist devices. Originally developed at Marshall Space Flight Center to allow astronauts to perform various control functions while they were immobilized by high gravitational forces, the device uses sensors mounted on eyeglass frames to sense eye motion. The signals generated by the sight switch system can be used to control a wide variety of devices.

The sight switch has helped patients control various orthotic devices as well as wheelchairs. The switch allows a person to start, stop, reverse and turn the wheelchair by eye motion alone. By helping patients to control orthotic and pick-up devices, the switch permits many daily functions for which they would otherwise be dependent on others.

Traditionally, such patients have used the movements of various muscle or body parts to activate the drives and linkages which might be used to control an artificial grasping device or hand. But some patients particularly suffering the complications of spasticity or muscle-tremor have considerable difficulty operating conventional mechanical-control devices. The sight

switch relieves these problems by providing an on-off, all-or-nothing switch which is not likely to be accidentally actuated.

The sight switch has been evaluated and compared with several alternative control devices and has been found well-suited to certain device-control requirements. It is anticipated that the device will be applied throughout the nation in hospitals and in facilities providing extended care for quadriplegic patients. By restoring various control capabilities to persons previously unable to perform even simple functions for themselves, the positive impact on the daily live of totally paralyzed persons will be considerable. To make the medical community aware of the benefits of the device, several special publications and demonstration projects are being prepared.

To explore a range of eye-switch and other aerospace-derived patient-assist devices, NASA Marshall Space Flight Center has built a fully instrumented room which will allow paraplegics, paralysis patients and amputees to control all of the equipment and devices in their hospital environment. Installed for evaluation in the rehabilitation center at the Huntsville Hospital, the system will enable patients to control room lights, a page turner, a radio or TV, message panels and a variety of servos capable of controlling appliances, bed positioning and even a telephone.

A variety of patient-control switches will be available to permit matching of control switches with individual patients' physical abilities. Some patients are able to turn their head and neck to either side. Others may be able to control the movement of a finger or toe. Even patients with extreme disabilities can usually produce a directed puff of air which may then be used to actuate a microswitch.

Extensive testing has proven the feasibility and operational capacity for each of the alternative switches, within the capabilities of the patients

who would use them.

Installation of the system is now complete and evaluation is in progress.

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HEAD-INJURY DIAGNOSIS

In response to a request from the University of Texas at Galveston School of Medicine, NASA circuitry is being applied to the development of an improved technique for monitoring fluid pressure within the skull. The pressure is measured by an implanted transducer, the response of which is continuously telemetered to the monitoring instrument without encumbering the patient with inconvenient hardware hookups.

Injury to the brain as a result of head trauma results in swelling and increased intracranial pressure that reduces the blood supply to delicate tissues. This condition can lead to inadequate oxygenation and cell death. Medication is available to reduce the intracranial pressure by drawing fluid from the brain, but accurate measurement of the pressure is needed to guide the dosage of drugs and to assess their effects.

Conventionally, a pressure transducer, mounted on a burr hole that must be drilled through the skull, is used to monitor pressure in the cerebrospinal fluid. The conventional transducer is connected to the electronics and recording system via wires. But such connections can serve as paths for infection. Also, encumbering wires have to be relatively short and the associated equipment has to be close to the patient.

The applicability of NASA circuitry to this problem showed up in a search of the NASA data bank initiated by the Biomedical Application Team at the Southwest Research Institute. A prototype of the new "wireless" device has been built there.

While the present prototype is about one cubic inch in size, further miniaturization is easily achievable. Laboratory tests of the prototype have been successful and it has been delivered to the University of Texas at Galveston where clinical evaluation is now in progress.

AEROSPACE VALVE FOR URINARY CONTROL

NASA technology is aiding in the development an implantable urethral valve for use by incontinent patients.

The project started because of an inquiry from a medical researcher treating paraplegic patients. He saw a need for a simple, reliable and totally implantable urethral valve which could be easily controlled by the patient. A NASA engineer suggested that a valve similar to the one used in manometer tubes might solve the problem. The valve is now included in the design of an implantable control system.

Using the device, the patient will be able to mechanically control his urination by applying pressure to a small air-filled bulb implanted under his skin. The design of the bulb involved a search of NASA technology for a biocompatible material that would also withstand constant exposure to the chemical actions of urine. The Biomedical Application Team at the Research Triangle Institute located a material that met these requirements. Initial problems encountered in fabricating the material into bulbs and tubing were mastered.

Five prototype systems have been fabricated and delivered for laboratory testing in dogs at the University of Virginia to determine if there are any unfavorable long-term effects. The tests could lead to mass production of the unit. This could benefit as many as 15,000 patients a year.

The bulb may also be useful as a drainage-bag valve for externally mounted leg-bag urinals. This could be a boon to spinal injury patients many of whom wear such devices and who lack the muscular coordination to drain them. This

leads to an embarrassing and inconvenient dependence on others. Since the ability to make a fist and push on an object are among the few controlled muscular actions such patients can perform the bulb-controlled valve appears to answer their needs. Also, since implantation would not be required for such patients, the device could be manufactured at low cost using conventional materials.

PROSTHETIC-CONTROL SYSTEM FOR PARALYZED PATIENTS

NASA systems originally devised for the control of remotely-operated mechanical hands and manipulator devices in hazardous environments are being successfully adapted to assist paralyzed and amputee patients. The technology of NASA's space-oriented program has been combined to produce an upgraded proportional-control system which vastly increases the dexterity with which a totally paralyzed or amputee patient can use a prosthetic arm or hand.

Since most patients equipped with currently available artificial-hand devices have trouble handling power tools, rehabilitation researchers have been seeking improvements in manipulating capabilities in order to expand self-reliance among the handicapped.

Adapting a powered terminal device known as MATH, used in conjunction with proportional-control techniques, a prosthetic device has been developed which allows an amputee to use his prosthetic to operate power tools such as electric drills, soldering guns, etc. Control of the device is positive and delicate enough to permit handling and drinking a hot cup of coffee.

The proportional-control system is also being used to control complex manipulative devices that may restore a large degree of independence to patients by allowing them voluntary control of their paralyzed arms.

Until recently, externally-powered orthotic arm braces with as many as seven joints - and thus seven reversible motors - were controlled by

simple on-off switches. Prior to the introduction of the NASA proportional-control devices, it was difficult to achieve smooth, accurate motion control with so many working joints.

Incorporated into the seven-degree-of-freedom externally-powered orthotic arm brace, the proportional-control system provides both velocity and force proportional control of the seven small direct-current motors. Now in daily use at Rancho Los Amigos Hospital in California, the proportional-control system enables a totally paralyzed patient to perform tasks requiring considerable accuracy and dexterity. The control is "fine" enough to permit many routine tasks, self-feeding, drinking from a cup, turning pages, dialing a telephone and even writing legibly. Using a typewriter with a specially modified keyboard, one paralyzed patient is now able to type 22 words per minute.

RECHARGEABLE CARDIAC PACEMAKER

Aerospace technology originally developed for rechargeable nickel-cadmium cells for spacecraft power systems is being directly applied to a NASA-supported effort by the Johns Hopkins Applied Physics Laboratory to produce a rechargeable cardiac pacemaker. The new unit would eliminate the present requirement for surgical replacement of pacemakers when their batteries are depleted. Currently, nearly 90 percent of the pacemakers using conventional mercury batteries must be replaced every 24 months due to battery failure. A rechargeable-unit wearer would simply recharge his pacemaker by donning a special vest for several hours. This would be particularly beneficial to infants and aged patients.

The rechargeable unit has already been tested successfully on dogs. Beyond rechargeability, it offers other significant advantages. Since it does not require a large battery, it can be drastically reduced in size--down from the present 8 cubic inches to a unit one quarter that size.

Use of a hybrid circuit also helps cut down size and weight. Also, unlike current pacemaker units which begin to lose their energy as soon as they come off the production line, the rechargeable pacemaker can be kept at a safe charge level until it is implanted in the patient. The new device also has a telemetry system that measures battery voltage and charging current.

The aerospace-derived hermetically sealed nickel-cadmium power cell is the key to the unit's operation. This power cell is essentially a miniature version of cells used in most U.S. spacecraft. The hybrid

circuitry, a technology to which Johns Hopkins Applied Physics Laboratory had made major contributions, offers great advantages in circuit reliability as well as weight and size reduction.

Further evaluation of tests on animals will precede implantation of the new device in humans.

IMPROVED INSTRUMENTATION FOR DRUG DETECTION

A recent Urban Technology Conference devoted to examining the role that NASA technology could play in solving some problems currently facing many cities of the United States highlighted the need, in New York City particularly, for the development of new instrumentation for drug detection. As a result, NASA is assisting in the development of such equipment. Although analytical instrumentation currently exists, there has heretofore been no combination of techniques and instruments that include all the necessary features to provide low-cost, accurate and portable instrumentation for the rapid, reliable, and routine determination of drugs.

The seriousness of the heroin problem, and the fact that heroin is broken down into morphine derivatives when injected into the body, prompted interested scientists at NASA's Ames Research Center to give priority to morphine detection. This effort was a natural adjunct to ongoing research into chemical factors impinging on pilot stress. Preliminary chromatographic-column work has shown that it is feasible to detect morphine quickly and unequivocally. The equipment currently in development consists of a simple, self-scanning spectrofluorometer designed for use with column chromatography in the detection and identification of morphine in the urine. Chemical treatment of a urine specimen converts morphine, which is weakly fluorescent, to a highly fluorescent fluorophore. The compound is then introduced to the chromatographic column and the morphine moves as a band down the column under standardized column conditions. The column is irradiated with monochromatic ultraviolet radiation.

The detector system simultaneously measures the fluorescence spectrum characteristic of morphine, the rate of movement of the band down the column

IMPROVED FIREMAN'S BREATHING APPARATUS

NASA's attention to the problem of developing a new type of fireman's Breathing Apparatus originated in the need of municipal fire departments for improvements to such devices. While conventional apparatus has been available for some years, many fire-fighters neglect to use it because of restricted mobility and vision. This had led to a discouraging rate of smoke-inhalation injuries.

In cooperation with the National Bureau of Standards Office of Fire Research and Safety and Public Technology, Inc., NASA launched an effort in the Spring of 1971 to develop improved equipment. Cities were polled on their needs, and a User Design Panel was formed comprising fire chiefs, city managers and a representative of the Office of Fire Research and Safety of the National Bureau of Standards. The first Panel meeting identified the main problems in currently-used systems and it was agreed that NASA technology in life support systems, developed principally at the Manned Spacecraft Center could be applied to the development of a more efficient apparatus. Of specific relevance to increasing the duration of the air supply and reducing the total weight of the equipment was technology developed by NASA in the use of filament winding techniques which allows the construction of stronger and lighter containers as compared with conventional methods. This technology was applicable to the manufacture of the pressurized air containers with a potential of reducing the system weight by 30 percent. Other proposed improvements included making the system more compact and changing the shoulder mounting of the device to a more comfortable hip position. The User Design Panel agreed that such a development program was desirable.

Three contracts have now been awarded by NASA, two for different configurations of the pressurized air containers and one, to Scott Aviation, for the complete system. With the participation of the User Design Panel and after extensive testing by the Manned Spacecraft Center, the equipment will be released for field tests by firemen in a number of cities in December, 1973.

FIRE PROTECTION OF RAIL TANK CARS

NASA is working with the Association of American Railroads and the Federal Railroad Administration on the continuing problem of railroad tank-car safety. One aspect of the study involves exploration of materials to protect tank cars in post-derailment fuel fires. A protective coating is needed to prevent the steel tank car shell from reaching a temperature of 800°F within a period of a half an hour to four hours. This need is underscored by the fact that the damage radius of the fire that usually follows derailment can spread appreciably by further rupturing tank cars as a consequence of severe heat loads. Application of NASA Technology toward meeting this public sector requirement was initiated by the Stanford Research Institute NASA Application Team, which contacted the Chemical Research Projects Office at the NASA Ames Research Center. This office has done extensive work in the development of materials for fire protection of aircraft and spacecraft.

After discussions with the Association of American Railroads and the Federal Railroad Administration it was determined that a fruitful approach would be for the Chemical Research Projects Office at Ames to direct a program to define the heating-environment and to evaluate the response of various thermalshield materials in railroad tank car fires.

Initial fire tests are being funded by the Federal Railroad Administration and will be performed at White Sands, New Mexico in the winter of 1973. Ames staff members will participate in these tests.

LOW-VOLTAGE SWITCHING AND FLAT CONDUCTOR CABLE

NASA wiring technology is helping to simplify and reduce housing construction costs.

The switching circuit commonly used in conventional electrical wiring of residences and buildings is expensive. Standard wiring practice uses a switch in series with the fixture to be switched. This necessitates bringing a power circuit from the fixture to the switch location. There are a number of problems associated with switching circuits installed in walls. In some new systems of construction, walls are very thin, leaving little room for conduit and switch boxes. In panelized and prefabricated construction there is still significant on-site labor associated with fishing wires through conduit. If there is a malfunction it is very difficult to repair embedded wires; and rewiring can be costly in the rehabilitation of older buildings.

An investigation of alternative and less costly methods for the installation of electrical switches and walls was requested by the New York State Urban Development Corporation (UDC). The low-cost solution suggested by one of NASA's Application Team, Abt Associates, involves the use of a low-voltage switching device developed by the application of aerospace technology and flat conductor cable from the Marshall Space Flight Center.

The system, called Surfacepack realizes savings by eliminating the conduit network required for the switch leg of conventional circuits and by surface-mounting the switching circuits. The flat cable is adhesive-backed, mounted to effect a low profile (only 4 mils thick) and is easily obscured by paint. The simple, inexpensive switch that accepts the flat cable can also be easily mounted. New buildings designed to accommodate Surfacepack need only provide on-site horizontal power runs, going up or down for outlets and/or fixtures.

Several meetings were held with manufacturers to discuss adaptation of low-voltage switching devices to the flat conductor cable. A small company, Non-Linear Systems, that produces electronic parts and equipment for the aerospace industry expressed strong interest in this technology and developed with its own funds the necessary low-voltage solid-state switching device.

Because of its innovative nature, Surfacepack was chosen by Industrial Research magazine as one of the most significant 100 new products of 1971. Surfacepack has also received national news coverage and has been featured on national television.

Surfacepack received its Underwriters Laboratory approval in May, 1972. It is now being marketed by a subsidiary of Non-Linear Systems, Switchpack Systems Inc. It is estimated that the new technology could cut the cost of installing electrical switches by \$15 to 35 per switched fixture in new construction. Even greater potential savings in rehabilitation and renovation projects are expected.

As a follow-on effort, the Marshall Space Flight Center is developing a flat conductor cable to carry power circuits for residences. This is another application of previously used aircraft and spacecraft technology. The aims of the program are to bring about revision of electrical standards and to provide the building industry, and New York State Urban Development Corporation in particular, with a totally new and planned electrical system. Problems to be solved during development include connection and termination techniques, wiring system hardware development, installation, routing, attachment, and safety techniques.

The New York State Urban Development Corporation (UDC) has expressed its commitment to the flat conductor cable development project and its intention to install, on an experimental basis, a house voltage surface-

mounted wiring system in 10 apartment units. A special UDC Advisory Committee on electrical systems will be created to assist with this project. Two contracts were awarded in the late fall of 1972 to develop and test hardware for UDC use. Tentative plans call for installation and evaluation of the hardware by mid-1973.

A LOW-COST RELIABLE FIRE-WARNING SYSTEM FOR MASS HOUSING

NASA is working with the Department of Housing and Urban Development on early smoke detection. Also deeply concerned with the problem is the National Commission on Fire Prevention and Control. The requirement was underscored in HUD's Guide Criteria for Operation Breakthrough. The Guide Criteria requires that smoke-detection and alarm systems be installed in multilevel dwelling under the program's sponsorship.

Alternate technological approaches for a solution were reviewed by Abt Associates, the NASA Application Team concerned with housing. These included infrared, ultrasonic and ultraviolet detection methods. Specialists also suggested as a solution a new polymeric material, polyphenylacetylene, with electrical properties that change as it absorbs gases or particulates. The polymer acts as an effective contaminant-detection device when it is used as a coating on a field-effect transistor (FET). The FET can detect the polymer's changing electrical properties and actuate an alarm device. McDonnell-Douglas Corporation had earlier synthesized such a polymer and developed a contaminant-detection device for use on the NASA Mars-Voyager mission. The Federal Housing Administration, McDonnell-Douglas, the Massachusetts Institute of Technology and the National Bureau of Standards have worked together to develop design criteria for the early-warning system using adapted aerospace technology.

Currently, McDonnell-Douglas and the Massachusetts Institute of Technology are planning development of the detection device for application to residential structures. Plans call for work to begin in 1973. During the first year of effort feasibility will be further established. It is estimated that three years of development will be required before a device will be ready for commercial sale.

RESCUE VEHICLE FOR USE IN COAL MINES

In its search for technology applicable to disaster rescue the Bureau of Mines has funded research at the University of Kentucky to develop an unmanned remotely-controlled rescue unit. To assist the project, NASA's Application Team at the Illinois Institute of Technology Research Institute explored available NASA technology and found that guidance system technology developed by the Marshall Space Flight Center for the NASA Lunar Rover vehicle appeared to be particularly relevant. The Bureau of Mines has agreed to jointly fund with NASA the adaptation of the Lunar Rover guidance system for use in an unmanned mine rescue vehicle.

The only basic design change required of the Lunar Rover guidance system is simplification of the system's readout. The system consists basically of an odometer to measure distance traversed, a directional gyro to give bearing relative to a fixed reference (such as North) and a processor to take the odometer and gyro data and convert it to X and Y coordinates.

Tentative plans project delivery of the adaptated Lunar Rover guidance system to the University of Kentucky for installation in the vehicle in the late winter of 1973.

RECYCLING NONFERROUS METALS FROM SCRAP

Based on early work at the NASA Lewis Research Center and a continuation of this under NASA contract by the Avco Corporation, recently developed techniques based on the properties of magnetically responsive fluids known as ferrofluids are being employed in the development of a prototype device that will separate previously wasted nonferrous metals from scrap materials and make it commercially feasible to reclaim and recycle these valuable substances.

Ferrous metals have been reclaimed with ease for years but until recently the cost of separating nonferrous metals has made it difficult to do the same for them.

The method under study involves a technique called sink-float separation that is based on the ability of ferrofluids to show a variable apparent density in the presence of a magnetic-field gradient. Control of the apparent density of the ferrofluid can be put work to separate a mixture of nonmagnetic particles into measurable fractions of different density, thus breaking out the nonferrous metals.

Under contract to NASA's Langley Research Center, Avco Corporation of Massachusetts is designing, building, and will test a prototype sink-float ferrofluid separator able to sort out mixed nonferrous scrap metal mixtures including shredded automobiles. The proposal to perform this work was referred by NASA to the Environmental Protection Agency who reviewed it and encouraged NASA to proceed. Continuing liaison between NASA, Avco and the Solid Waste Research Laboratory of EPA will ensure an objective evaluation of the performance of the prototype as a preliminary to full scale tests and commercialization of the process.

LIQUID METAL MAGNETOHYDRODYNAMICS FOR POWER GENERATION

To help meet the energy crisis NASA's Jet Propulsion Laboratory (JPL) at Pasadena, California is currently assessing the potential of liquid-metal magnetohydrodynamic (LMMHD) technology as a power source. LMMHD is based on the use of a heat source that produces a high-velocity electrically conductive fluid stream that interacts with a magnetic field to produce electric power. The potential advantages of LMMHD over conventional steam plants include savings in fuel, with attendant reductions in waste heat and emission--both of which create environmental problems. Also, capital costs are potentially lower because with LMMHD there is no need for conventional turbomachinery.

Jet Propulsion Laboratory's LMMHD technology transfer feasibility study has examined the various technical, economic and environmental aspects of liquid-metal MHD as compared with alternative systems, defining applications for which the new technology seems superior. The purpose of the study was to create a fund of reliable data that will be readily available to potential users. To ensure the cooperation of potential users, a User Review Board comprising representatives of electric utility companies, electrical power associations and component manufacturer was established to work with JPL to provide data to the study and analyze JPL's work. The final report has been circulated to the members of the Board, whose reaction to the study is uniformly favorable. It is the first time that a comprehensive review of the state-of-the-art in this field has been made and the Board considers it a vital and essential first step towards the technical and economic development of LMMHD.

IMPROVED AIR POLLUTION DETECTION

Charged with the responsibility of specifying a measurement method for formaldehyde, an eye-irritating product of auto induced air pollution, the Environmental Protection Agency has enlisted the aid of NASA through the Research Triangle Institute Application Team in a search for aerospace technology that might be used to detect concentrations of this chemical which may also play a role in the formation of smog.

A scientist at NASA's Langley Research Center suggested the use of microwave spectrometry, which is used to measure formaldehyde and other pollutants in space-cabin atmospheres. The aerospace-based technique offers significant advantages over currently available wet-chemical techniques that are cumbersome, time-consuming and subject to various forms of interference.

NASA and the Environmental Protection Agency are jointly funding a project to develop miniaturized gas analyzers to serve the formaldehyde measurement mission. A contract has been awarded to the Lawrence Radiation Laboratory in California to develop a practical instrument design that would employ modern solid state technology and be producible at low unit cost. Researchers expect a prototype instrument to be completed and delivered to NASA for evaluation by the Environmental Protection Agency during the summer of 1973.

AN ADVANCED POLLUTANT SENSOR FOR CARBON MONOXIDE

In response to a significant problem raised by the Environmental Protection Agency--the detection of harmful concentrations of carbon monoxide in the air--a sensor that was originally designed for use in the NASA Skylab program and for cabin-atmosphere monitoring on nuclear submarines has been made available commercially. Other applications include air-monitoring inside commercial aircraft and medical applications such as metabolic rate determinations and anesthesiology.

The device, produced by Andros Incorporated of California, is based on the absorption of nondispersive infrared radiation (NDIR) by carbon monoxide molecules and the fact that molecules of different gases present different infrared "signatures" which can be read for monitoring.

This fluorescent source NDIR detector offers higher sensitivity, improved freedom from interference, better maintainability, a high degree of portability and good stability as compared to other similar devices. It is already being used for a number of air-monitoring missions by government agencies, research organizations and industrial firms.

(which is further confirmation of that compound) and the spectral amplitude, which gives a quantitative measure of the amount of morphine present in the urine specimen.

A contract has been awarded to Whittaker Corporation for the fabrication and delivery to NASA, of four instruments, two of which will be sent to the U.S. Army Walter Reed Institute of Research and a third to the New York City Health Department for field evaluation. The fourth will be modified to detect barbiturates, amphetamine and methadone.

A production instrument produced in quantity would be expected to sell for less than \$1,000.

MEASURING RAILCAR WHEEL AND RAIL STRESSES

Thermal stresses that build up in long and continuous railroad tracks can cause buckling and breaking. This happens when the uniform distribution of these heat-induced stresses is disturbed by improper alignment of ties, ballast or rail anchors. An effective, rapidly applied method of non-destructively detecting high pre-yield stresses is needed for use by rail-inspection crews in the maintenance of such rail sections. Another railroad problem is derailment caused by catastrophic failure of railcar wheels. Such failures are caused by stresses resulting from known vertical and lateral loads superimposed on unknown residual stresses in the wheel. A method is needed for inspecting railcar wheels in the field, to determine whether residual stresses are above a critical level. Application of NASA technology in this area was initiated by the Stanford Research Institute Team at the request of the Federal Railroad Administration.

Ultrasonic techniques of measuring stress are currently being developed at the NASA Marshall Space Flight Center for the nondestructive testing of spacecraft structures. These are based on earlier work by a Marshall contractor reported in NASA Tech Brief 67-10428 "Ultrasonics Used to Measure Residual Stress." They appear to have great potential application to rail problems since they are effective for measuring stress in specimens made of well-characterized materials with uniform, reasonably flat smooth surfaces.

A program was funded in late 1971 to:

1. determine the ultrasonic velocity vs. stress relationships for the particular types of steel used in making wheels and rails;
2. investigate the effects of temperature variations on the accuracy of stress measurements;

3. evaluate measurement problems related to rail geometry;
4. make actual stress measurements on wheel and rail segments under controlled laboratory conditions; and
5. demonstrate the practicability of the technology by making stress measurements on long rail segments under realistic field conditions.

Initial testing has included obtaining data relating shear-wave determination of stress levels with applied loads. The data confirmed that applied loads can be accurately measured by the resulting stress as measured by ultrasonic shear-wave methods.

The Association of American Railroads has provided samples of rail and wheels and has closely followed the tests. The Federal Railroad Administration has provided most of the funds for this project. If the laboratory work proceeds as scheduled the field test should be conducted in the summer of 1973.

APPENDIX C

to the

STATEMENT OF

CLARE F. FARLEY

Deputy Assistant Administrator for
Technology Utilization

Industry Activity in Technology Transfer:

A Report by the General Electric Company

THE GENERAL ELECTRIC COMPANY

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The 60's have been labeled as the decade of development--- a time when America experienced its most explosive period of technological advance---and the space program was the dominant influence in this extraordinary advance of technology.

America's historical willingness to invest in science and technology has made possible the world's strongest economic system and the highest standard of living for its citizens. For science and technology leads to new products---and new products make possible a better life within the country and a more competitive trade position on the world market.

Now the formidable fund of knowledge gained from space research is being tapped to help solve many of the problems that have been assigned a new national focus. The impact is already evident in matters of clean energy, pollution abatement, housing, waste disposal, health improvements and a wide range of other positive attacks on critical social and economic concerns.

Aerospace companies have been quick to adapt the new technology to the new priorities. One of these firms is General Electric---a key contributor to Apollo, to Nimbus, to the Earth Resources Technology Satellite and many other NASA programs. General Electric has taken technology developed in these programs and transferred it to help meet many of the nation's needs.

Though General Electric is advancing this movement on a hundred different fronts, the breadth and importance of these efforts can be keenly demonstrated with the following typical programs:

1. THE PACEMAKER---Miniaturization techniques, perfected in the space program, are a key part of the pacemaker which, implanted in the chest, helps heart patients maintain a normal rate of heartbeat. The pacemaker became possible through development of low power circuit transistors and high energy density batteries, and now microcircuits have greatly extended the life of the pacemakers and made possible useful lives for thousands of people. General Electric is producing literally thousands of microcircuits for the pacemaker, fully utilizing space reliability techniques.

2. SOLID WASTE MANAGEMENT SYSTEM---Space program experience in establishing major technical facilities such as the Mississippi Test Facility, and in performing complex system optimization studies, is being applied to solve the solid waste problem on a state-wide basis for Connecticut. General Electric is well beyond the halfway mark in the design study for that system. A potential pacesetter for the nation, the system will be effective, practical, economical and socially acceptable.

3. AIR POLLUTION MONITORING SYSTEM---An Air monitoring system, called COPAMS, has been set up by General Electric for the entire Commonwealth of Pennsylvania. Using the remote monitoring know-how of the space program, the project calls for setting up as many as 32 stations with a central control station located in Harrisburg, the state capital. The system monitors conditions of the air and provides a complete readout of air and meteorological conditions once every minute. Air monitoring operations have also been conducted at

multiple sites in New York and New Jersey by General Electric. In addition, a Mobile Lidar System is being developed for measurement of stack-plume opacity. The device is a laser radar or lidar (light detection and ranging) system which measures light backscatter caused by atmospheric particulates (aerosols) at ranges to several miles.

4. THERMOCASE PIPELINE---By adapting spacecraft super-insulation material and thermal analysis techniques, we are now successfully insulating arctic pipelines and oil well casings so that the developers of newly-discovered oil fields on the Northern Alaskan Shelf can drill and relay pipeline oil to various distribution points without disturbing the ecology. This is particularly critical in view of the growing energy crisis in the United States.
5. GAS SENSORS---An oxygen partial pressure sensor originally developed for manned space flight life support systems was first adapted for the General Electric "backpack"---a lightweight underwater breathing system.

The sensor has subsequently been adapted for use by hospitals in baby incubators, and now to a controlled respirator used for open heart surgery at Bethesda Naval Hospital. These same sensors are being used to insure the proper operation of the cooling systems of nuclear reactors.

6. CONSUMER ELECTRONICS---Technology developed and used in the Aerospace industry has provided the basis for considerable improvement in the Consumer Electronic businesses of the General Electric Company. Two technologies which have already had a major impact and will continue to reflect on the performance, reliability and cost of various consumer electronic products are integrated electronics and signal processing techniques. The ability to fabricate complex integrated circuits containing large numbers of active devices has made possible the introduction of sophisticated aerospace signal processing systems into consumer products. These technologies have simultaneously provided reduced customer costs with improved reliability and performance. By utilizing

advanced feedback techniques, phase locked loops, etc., critical adjustments and alignments in color and monochrome television receivers have been significantly reduced, thereby reducing factory costs as well as providing reliable, improved performance. Similar techniques have been applied to AM and FM receiver systems. These integrated circuits are already in production in many of the chassis of General Electric's products and a continuing effort to utilize these technologies is presently planned.

7. HOUSING---Utilizing space systems management and space developed manufacturing techniques and materials, General Electric has vividly demonstrated that factory-built modular housing can be economical to build, attractive and comfortable to live in. With housing already pinpointed as one of the great national needs, continued development of this process is necessary to meet the growing requirements in all parts of the country. The General Electric approach has already been successfully demonstrated in homes for military

personnel and families at George and Norton Air Force Bases in California and urban projects developed in Memphis and Indianapolis.

8. UNDERWATER HABITATS---With the world looking more and more to the oceans as a source of support, General Electric took early technology developed for the life support systems of the manned space flight program and developed the underwater Tektite habitat. The most ambitious underwater research program ever undertaken, Tektite has helped determine the capability of man to satisfactorily perform long duration undersea scientific research missions while continuously living on the ocean floor under saturated diving conditions for the long periods of time involved. This is a giant step in enabling man to better tap the great resources of our oceans.
9. THE FUEL CELL---The SPE (Solid Polymer Electrolyte) fuel cell, developed as a power source for the Gemini spacecraft, has fostered two product areas---water electrolysis and oxygen concentrators.

Water electrolysis can generate pure oxygen in the home to aid patients suffering from respiratory ailments. Out of this work has come a small, compact hydrogen generator that is a hydrogen source for flame ionization detectors used in mobile vans as pollution monitors. Water electrolysis can also produce an oxygen generation system on nuclear submarines, offering an 80 percent savings in weight and requiring 50 percent less power.

Also from the fuel cell technology oxygen concentrators have been developed which can supply 99.5 percent purity in the oxygen supply to an aircraft crew, greatly improving safety conditions; can aid water purification methods by using reverse osmosis with great potential for cleaning up industrial sewage; and catalytic electrodes can be used to produce automotive exhaust monitors and can also be an alcohol sensor to monitor drunken driving. And these are but a few of the potential benefits from the fuel cell originally developed for Gemini.

10. HAZARDS ANALYSIS---General Electric did an extensive "hazards analysis" on the Apollo Program which was an identification of all possible malfunctions, corrective actions and remaining capability of the system. It also identified desirable design changes and operating modifications. This same "hazards analysis" technique is now being used to assure the reliability and safety of off-shore oil drilling projects, as well as for nuclear power plants.
11. DATA MANAGEMENT---Because of our in-depth data management work on Apollo, General Electric is working with the Law Enforcement Assistance Administration (LEAA) in devising and operating an information clearinghouse on law enforcement. This system, utilizing a computer information bank in Washington, D. C. enables law enforcement officers in various parts of the country to obtain needed information in real time. We are also under contract with HEW to provide a national clearinghouse for data on alcoholism and alcohol abuse, and we are proposing a similar effort for the National Cancer Institute and other agencies.

12. CLEAN ENERGY---In the realm of clean energy systems. General Electric has been working on a spectrum of space-derived technologies applied to the twin crises of pollution and energy. For example, we have taken liquid metal technology from our space nuclear experience and devised a present state-of-the-art "liquid metal topping cycle" to be added to existing steam generating plants, offering significant increases in operating efficiency and decreases in pollution. The liquid metal turbine accepts superheated steam, generates electricity and then exhausts the steam at exactly the correct inlet temperature for the existing steam turbine. This has been the subject of recent proposals to the National Science Foundation and the Electric Power Research Institute.

13. BIOMEDICAL EQUIPMENT---As a result of our work in the manned space biomedical technologies, we developed several specific equipments and techniques. The latest example is pre-stained slides, which are fully prepared to render liquid samples, such as blood and

urine, for immediate analysis, eliminating the need of sending these samples to a laboratory. Among the many advantages of this measuring system are accuracy, and time and cost savings. The pre-stained slide technique is now licensed to multiple suppliers in the medical equipment field and about to be introduced on a major scale.

Again, these examples represent only a few of the areas where General Electric is taking the technology and converting it into the needs of Earth. These successes and those of other aerospace firms pursuing technology transfer illustrate the need for this nation to continue its commitment to a strong space program.

A society that continues to invest part of its annual income in the future is a progressive society and history has never known a more productive, a more peaceful means for advancing the quality of life of its citizens than the space program. To turn away from progress in space is also to reject progress on earth.

We stand on the threshold of more incredible achievements in space and in science and technology across all fronts. At the same time, an avalanche of benefits on earth to our health and well-being awaits us. The key is a continued advancement of the space program as a national pacesetter.

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APPENDIX D

to the

STATEMENT OF

Clare F. Farley

**Deputy Assistant Administrator for
Technology Utilization**

Examples of Technology Transfer

by Regional Dissemination Centers

IMPROVED THERMAL INSULATION FOR SUB-SURFACE INSTRUMENTS

The well-surveying instrument industry is intensely competitive. Continuously improving technical performance of such instruments is essential in order to stay in business. Thermal protection of the instrument is crucial. In this connection, the chief engineer of the Kuster Company, Long Beach, California has obtained outstanding results from a search of NASA developments in thermal insulating materials, performed by the Western Research Application Center (WESRAC).

In commenting: "We could not have done it without WESRAC's assistance," the chief engineer confirmed the satisfactory development of a new insulating technique for the firm's instruments. The technique incorporates an insulating material which is virtually a direct application, with minor modification, of a material developed in the space program. Several months of search time and development were saved, representing considerable dollar savings. Further, the speed of introduction of the innovation gave the company an additional competitive edge.

FETAL-HEART MONITOR

One example of RDC assistance in a client's product diversification efforts relates to the transfer of technology developed by NASA for monitoring the physiology of astronauts.

A New England company was interested in expanding its line of medical monitoring equipment. It contacted the New England Research Application Center (NERAC) for help. Discussions with company engineers led to a very general search of the NASA data bank on the subject of medical monitoring. A review of the computer printout by company personnel suggested the use of ultrasonic techniques, already being employed in the manned space program, in a fetal heart monitoring instrument.

As a result, the company is now producing and marketing a fetal heart monitor using these space-derived ultrasonic techniques.

NEW COMMERCIAL BATTERY SYSTEMS

A successful line of high-energy-output batteries is providing sure, fast starts for portable power tools and sports equipment, based on battery technology originally developed by NASA.

An industrial firm used NASA technology to develop reliable starting of chain saws and outboard motors, and the batteries have been incorporated in electrical systems providing power supplies for golf and baggage carts. Other applications are being developed for medical devices such as portable EKG equipment, photographic strobo flash units, and toys and other appliances.

In conducting its research in the development of both nickel-cadmium and lead-acid cell batteries, McCulloch Electronics Corporation requested a review of NASA technology data in a search for innovations in the electro-chemical devices field.

The wide range of commercial possibilities for high-energy-output batteries prompted McCulloch to establish its new electronics subsidiary in Los Angeles. The NASA data bank search for promising battery technology was done for the firm by Western Research Application Center (WESRAC), the NASA regional dissemination center at the University of Southern California.

From this and other available data, McCulloch developed its own electrical power source system, incorporating several of its own patentable concepts, including both lead-acid and nickel-cadmium batteries capable of being recharged 90 to 100 times faster than existing batteries. Compared with most commercial batteries requiring 14 to 16 hours for full recharge, the new batteries can be recharged in 15 to 20 minutes without damage to the cells. Some nickel-cadmium units can be recharged in as little as 6 minutes.

In addition to providing short, high amperage bursts of power repeatedly in various starting applications without reducing battery life, the new power system offers wide prospects for use where prolonged power is required, as in golf and baggage carts and in many applications in portable medical equipment. Some of these requirements call for relatively low amperage outputs for periods as long as a month.

McCulloch worked with the General Electric Company to develop a rugged high-rate battery, incorporating for the first time a starter, generator, regulator and nickel-cadmium battery in its power system.

Much of McCulloch's current research is concentrated in lead-acid battery development with a view to applications in automotive and service cart electrical propulsion.

"It was not only the inestimable dollar value of the actual data NASA generated by its work, but the dollar value of the time this work saved us. We didn't have to do this vital preliminary investigation ourselves or pay an outside research organization to develop it," W. B. Burkett, Engineering Vice President for McCulloch Electronics said, in acknowledging the contributions of NASA-developed technology and the information service provided by WESRAC.

FLUIDICS AND FLUID LOGIC CONTROL DEVICES

The importance of a Regional Dissemination Center's awareness of advances in the state-of-the-art which have become sufficiently practical to find useful industrial application is illustrated by the results of a Fluidic Workshop sponsored at the University of Southern California by the Western Research Application Center (WESRAC), NASA and the Small Business Administration. The aim was to expose representatives of the business community to recent advances in fluidics control technology that uses fluid-dynamics phenomena to perform sensing, control and activation functions without the use of moving parts.

As a direct result, one small company (17 employees) was able to expand its business at considerable profit. Originally a designer, manufacturer and distributor of hydraulic machinery and systems, the company has been able to diversify into an associated field--that of fluid logical-control devices. It has become the local distributor for such products made by a prominent national manufacturer. It conducts monthly seminars on the subject for customers and anticipates substantial business volume growth as the result. Already the company's gross business is increasing at an annual rate of 13 percent in the face of a decline among competitors of as much as 45 percent.

Another beneficiary of the Workshop was a medical doctor who was associated with a small group of consultants concerned with medical-instrument development. He had become aware of cases of the unexplained deaths of apparently healthy babies. One tentative explanation is that unsuspected mucus in the nasal passage causes suffocation. As a result the consultant group is developing an instrument called a rhinometer to measure air flow and air pressure differentials in the nose and thus determine mucus removal requirements.

Information received at the Workshop, it has been estimated, had a dollar value in excess of \$100,000 in contributing to the development and use of the rhinometer.

A third attendee, representing a 12-employee manufacturer of container filling equipment was able to move his company into new areas of business. These include equipment for counting and filling containers for hazardous products such as solvents and adhesives. Four new systems have been sold by the firm since the Workshop and an increase in annual sales in these new areas of at least \$20,000 is anticipated for the future.

CLEANING TECHNIQUES

A New England company was seeking a method of removing a microscopic bacterial organism that was contaminating large stainless-steel storage and mixture vats. These tanks were used to produce antibiotics and the company's cleaning technique did not meet the Food and Drug Administration's requirements. The company needed a solution within 60 days and contacted the New England Research Application Center (NERAC) for help.

After investigating the many aspects of the situation with the engineer in charge, NERAC searched the NASA data bank for information on cleaning and clean-room technology. An analysis of the computer printout of this search revealed that the Marshall Space Flight Center had sponsored research to solve a problem concerned with cleaning space rocket fuel tanks. The result of this work had produced a chemical solution to the problem, and NERAC's client was able to adapt it for its own use.

Using NASA-derived technology, the company was able to solve its problem with only a single engineer and did not have to divert other personnel to form a trouble shooting team. As a result the company kept its production line in operation. It did not suffer from stoppage losses, raw material spoilage, unproductive labor or reputation damage. Also, a sizeable labor force remained gainfully and productively employed.

AVOIDING RESEARCH DUPLICATION

Three New England clients of the New England Research Application Center (NERAC) wisely decided to use NERAC's search services to check whether existing technology could solve or partially solve problems on which they were proposing to initiate R and D programs. In two cases the searches produced satisfactory solutions and in the third it was demonstrated that the proposed program of work would probably have been a failure.

BLOWER FANS

The first client needed technical design information in the field of fans. The company needed a special fan and had decided it should design, develop and produce a fan to its own specifications and requirements. A search of the NASA data base produced information about a commercially available fan that met the company's requirement. Since there was actually no need to develop the new fan, the company saved at least one month of research and engineering time plus production toolup expenses.

CLEAR ICE

The second client was interested in methods for the production of clear ice for use in one of the company's main product lines--soft-drink vending machines. The RDC search identified several patents that the company had failed to uncover. These helped the company further refine its own techniques without patent complications.

CHEMICAL COMPOUND

A third client researcher requested a search on applications for a specific chemical compound. After studying the results the researcher concluded that others had already attempted to do what he was thinking of trying and had failed. Approximately 200 hours of laboratory research time was saved.

PRODUCT DIVERSIFICATION AND IMPROVEMENT

The technical requirements of manufacturing companies can be extremely diverse. The merit of a continuing relationship with a Regional Dissemination Center in order to meet these needs is amply demonstrated by the experience of one medium sized New England company. Based in part on its work with the New England Research Application Center (NERAC) this company is now well on its way to manufacturing and marketing three new or improved product lines.

MOLDING AND EXTRUSION COMPOUNDS

In one instance, the company needed information about molding and extrusion compounds carrying special mechanical properties.

A telephone dialogue between the company engineer and NERAC staff identified the critical mechanical properties. A search of NASA and other data bases, produced information on a series of satisfactory materials. Laboratory experimentation with these substances led to a new product line of molding and extrusion compounds possessing "substantially superior" properties, especially at high temperatures and pressures.

As a result of this activity, the company has acquired a subsidiary and invested venture capital in order to expand its production capability in this field.

HIGH TEMPERATURE, HEAVY LOAD BEARINGS

A second product introduced by the company is a new line of high temperature bearings capable of taking heavy loads. A search at NERAC identified applicable thermosetting materials which physical properties were the result of special additives. NASA solid-lubricant technology was the source of much of this information. The results of the RDC effort have been used in the development of satisfactory compounds to the point

that the company is now a supplier of fabricated parts based on these materials and also produces raw stock for other fabricating companies.

FLAME RETARDANTS

The company has also developed a fire-retardant cellulose material using data identified by NERAC from a material flame proofing program carried out at NASA's Manned Spacecraft Center. The company's R & D program leading to the production and sale of this material is not yet complete but laboratory tests have been positive. The initial value was both in the time saved for the search and the breadth of the search. It produced alternative materials and compounds to investigate that were compatible with the company's system and processing techniques. Of even greater value, however, was the identification of a mechanism for degradation and the composition of the degradation products, the subject of one document identified by the search. This particular paper, along with its list of references, presented analytical techniques that could be used for identifying specific decomposition products of various cellulose materials. With this information a more knowledgeable and meaningful development approach was made possible.

The company now has a product with the highest Underwriter Laboratory rating for such materials and is currently qualifying a second material.

APPENDIX E

to the

STATEMENT OF

Clare F. Farley

Deputy Assistant Administrator for
Technology Utilization

Technology Transfers from
NASA to the Private Sector

TRANSFER EXAMPLES

The following transfer examples have been prepared from telephone interviews with Tech Brief/TSP* users. These examples illustrate both the role of Tech Briefs in making new technology available to persons and organizations outside the aerospace sector and the typical problem-solving environment that characterizes the nonaerospace applications.

While the tendency to evaluate each case in terms of some measurable economic benefit is ever-present, this is only one type of benefit that users of NASA technology are able to enumerate. Although they are difficult to quantify, other types of benefits can be even more important--new understandings of material behavior, increased technical skills, improved management capability, better maintenance techniques, technical breakthroughs on elements of a new product, and improved product quality are just a few of these benefits. The following interviews were conducted during January 1973.

TB 71-10089, "Wein Bridge Oscillator Circuit"

The Lockheed Electronics Company, under contract to the Manned Spacecraft Center, designed an oscillator circuit having few components and a stable output signal that is controllable between two and eight volts at frequencies of 0.001 to 100,000 cycles per second. Tau Electronic Products, Incorporated in Emporium, Pennsylvania (59752),** a manufacturer of electroluminescent devices and aircraft instrumentation, recently initiated the development of a new digital clock to be used in general aviation aircraft. The oscillator was used with minor modification as the timing circuit in the clock design. Field testing of prototype units is now underway. A company representative stated that cost savings in the design phase of the product development have already accrued, but declined to estimate the potential sales volume for the digital clock.

The Systems Division of Computer Sciences Corporation in Falls Church, Virginia (60256) used the oscillator circuit in a system under development for the Defense Communications Agency. The operations director of the project estimated that six weeks of design time were saved because the bread-board layout of the oscillator circuit was directly suitable to the systems application.

TB 70-10647, "Systems Approach Provides Management Control of Complex Programs"

North American Rockwell Corporation, under contract to the Marshall Space Flight Center, developed a systems approach for management control of complex development programs. The approach is based on an analysis-synthesis rationale, and it provides the necessary techniques to control a complex activity from conception to manufacturing operations. The National Data Buoy Systems Group, part of the Electronics Division of General Dynamics in San Diego, California (54821), develops and manufactures navigation, oceanographic and meteorological buoys. The Group received a contract award to develop electronic control systems for the National

Oceanic and Atmospheric Administration. The program management approach described in the Tech Brief and TSP was used to establish planning, implementation, and management procedures for the contract. Based on this experience, the Electronics Division has adopted the approach in an internal "Program Plan of Execution" which presently guides much of the Division's 60-80 million dollar annual volume.

The Upjohn Company in Kalamazoo, Michigan (60860), a major manufacturer of pharmaceuticals, fine chemicals, agricultural products, and polymers, used the management control technique in a similar way. While Upjohn found that individual development programs for new products could be effectively controlled by critical path methods, the company was faced with the problem of controlling a large number of different development programs simultaneously. The critical path methods were found insufficient to handle the numerous uncertainties which arise in a multi-product development program. Methods from the NASA TSP have been adopted for use in controlling manpower allocations, setting development priorities, and in consideration of options for development tasks.

TB 71-10158, "Effect of Size on Cracking of Materials"

The Jet Propulsion Laboratory developed a new theory which explains the relationship between the physical size of a material specimen and its tendency to fail because of the flaws or cracks that are always present in the material. The Chamberlain Manufacturing Corporation in Waterloo, Iowa (69566), a large manufacturer in the field of home improvement equipment, is producing air bottles for use in automotive airbag safety systems. Stringent quality standards are imposed on the bottle manufacturer because of the relatively high internal operating pressure required and the possibility of premature failure. The TSP first alerted the engineering personnel to the potential hazard of even minor imperfections which can grow to be serious flaws during the operating life of the bottle. The technical information provided in the TSP influenced the design, manufacture, and testing procedures used in producing prototype air bottles and will be further utilized in selection criteria for the bottles delivered under the procurement.

TB 71-10271, "Qualifications and Certification of Nondestructive Testing Personnel"

Broad experience in nondestructive testing of mission hardware gained by the Marshall Space Flight Center resulted in the preparation of a handbook which outlines personnel qualifications, certifications and selection. The Taylor Forge Group of Gulf + Western Manufacturing Company in Cicero, Illinois (67406) used the TSP in testing personnel to fill a new position for an NDT specialist in their manufacturing operation. A Taylor spokesman reported that having certified nondestructive testing personnel has enabled the company to bid successfully on more critical programs requiring welded manufacturing.

TB 71-10160, "Dropouts in Magnetic
Tape Recording and Reproduction"

An investigation of the cause for data losses, or dropouts, that occur in magnetic tape recording and reproduction processes was conducted by the Jet Propulsion Laboratory. The investigation yielded recommendations regarding certification of tapes and suggested precautions to minimize the possibility of using or creating faulty tapes. The Fototronic CRT/Intertype Division of Harris-Intertype Corporation in Cleveland, Ohio (71772) manufactures computer-driven typesetting machines. A field service engineer was able to respond to a customer's complaints concerning his company's equipment by verifying that the customer's problems resided in the magnetic tape itself. The NASA investigation demonstrated that data dropouts do occur, and it explained the mechanisms operating when this happens. This experience led Fototronic to include the NASA procedures for certifying tapes in the equipment service manuals supplied to their customers. Customer benefits include reduced equipment "downtime" and higher quality printed material.

TB 71-10302, "Hot Tap Thermowell Installation"

The Manned Spacecraft Center developed a method which permits the installation of valves and other apparatus such as thermowells in hot pipelines without interrupting the operation of the line. A supervisor in the Mechanical Division of Amoco's Whiting, Indiana refinery (75018) found that the NASA TSP represented a safer, low cost method of capping or tapping into hot oil lines, a common problem in petroleum refineries that can lead to extensive downtime. The TSP was photocopied and distributed to all operating, maintenance, and engineering personnel in company facilities throughout the United States. Since this technology represents an attractive repair procedure, the apparatus has been fabricated at Whiting in anticipation of its urgent use.

TB 71-10329, "A System for the Automatic Measurement
and Digital Display of Systolic and Diastolic Blood Pressures"

The University of Texas, under contract to the Manned Spacecraft Center, developed an automatic system for the measurement and display of systolic and diastolic blood pressures. In an effort to improve a commercial product line, Synergetics, Incorporated of Gainesville, Florida (76536), a small manufacturer of medical instrumentation (sales are approximately one million dollars per year), has incorporated a part of the NASA development. For competitive reasons, the company asked that the specific adaptation be held proprietary, since the technology is in the public domain. In addition to citing reduced development costs, the company stated that the TSP provided the technical foundation for the concept employed.

TB 71-10246, "Portable Circuit-Interruption Indicator"

Trans World Airlines, under contract to the Kennedy Space Center, developed a portable circuit-interruption indicator which was used to find transient power interruptions in electrical equipment such as air conditioning units, heating and ventilation equipment, and compressors and generators. Teledyne/Brown Engineering Company, Incorporated (66370), a wholly-owned

subsidiary of the Teledyne Corporation, learned about the indicator through its system of monitoring Tech Briefs. The company estimates that approximately forty hours of maintenance time are saved annually in providing engineering support to the Marshall Space Flight Center.

TB 71-10306, "Closed-Loop Control of Stochastic Non-Linear Systems"

A sophisticated, new control design technique was developed at the Massachusetts Institute of Technology under contract to the Manned Spacecraft Center. The technique was derived to solve optimum control problems in space vehicle guidance and navigation systems and closed-loop process controllers. Many control systems have characteristics that are either unknown or are highly variable, yet engineers must somehow take this into account when they design new systems. The NASA technique can handle a priori statistical information about the unknown parameters and does not require an artificial augmentation of the cost function as a basis for considering these unknowns. These two features provide an important improvement over previous techniques used for such problems. A major manufacturer (company name is proprietary) of electric generating equipment (67812) has used the TSP in developing a new surveillance system for nuclear power plants. The development has been underway for two years and represents a major research commitment; the product will be introduced in 1975. A method for handling nonlinear systems that was described in the TSP was very important in creating a computer program which provides estimates of nuclear processes through the surveillance system mini-computer. The product will be used as peripheral equipment on nuclear power plants to detect abnormalities in the nuclear process, improving safety and performance control information.

TB 68-10143, "Deep Gamma Ray Penetration in Thick Shields"

An analytic study conducted by the University of Tennessee, under contract to the Marshall Space Flight Center, provided an improved method for determining the necessary thickness of nuclear radiation shields. The improvement is based on using a specified importance function and sampling scheme with the standard Monte Carlo method. By using the new method, the calculation of gamma ray penetration can be significantly improved for the same computational time. Burns and Roe, Incorporated, a major design engineering company in Hempstead, New York (14155), needed a method for determining the shield thickness required to protect steam lines, turbines, and other components in nuclear power plants from radiation. After receiving the TSP, the company adopted the new method as its standard technique for shielding design. The technology has been used in designing the now operational Oyster Creek, New Jersey nuclear power plant, saving Burns and Roe three to four man-months of engineering time. Similar savings are anticipated on four other nuclear power plants which are under construction or being designed by Burns and Roe.

TB 71-10196, "Limited Life Item Management"

North American Rockwell Corporation, under contract to Marshall Space Flight Center, developed control plans, procedures, and complete specifications for the management of age-sensitive products. Materials used in gaskets, seals, lubricants, hose assemblies, batteries, adhesives, and fabrics will, if not replaced at scheduled intervals, deteriorate and create

safety hazards or cause system failure. The control plan identifies shelf life, or age-control, and presents methods for determining how the useful life of materials may be extended. The Tennant Company in Minneapolis, Minnesota (69356) manufactures powered floor maintenance equipment. The information in the NASA TSP enabled the company to establish inventory procedures which improved the reliability of its products. Certain rubber components were particularly troublesome because of their limited shelf life. By initiating distribution controls on these components, Tennant's customers are now able to obtain replacement items with longer functional lifetimes. The information was further helpful in informing the company's customers of the need for establishing their own schedules for the replacement of age-sensitive components to minimize downtime.

TB 71-10319, "Estimating Carbon Monoxide Exposure"

The North American Rockwell Corporation, under contract to the Manned Spacecraft Center, developed a method for predicting the effects of carbon monoxide on astronauts. Precise correlations of carbon monoxide poisoning, breathing rates, and variations in atmospheric conditions have been established. Two equations have been developed which make it possible to estimate the carboxy haemoglobin formed when carbon monoxide is inhaled and when adjustments for pulmonary ventilation are necessary. Aerospace America, Incorporated of Bay City, Michigan (77452) manufactures off road equipment, including fork lift trucks. Based on information in the NASA TSP, the research and development group initiated a program to meet anticipated emission control regulations. The TSP was a major information source which not only showed the necessity of their carbon monoxide emission reduction program, but also suggested directions for their internal program. The company expended approximately \$10,000 in this research effort and now feels it is in a position to relate progress in the automotive emission control field to its equipment.

* A Technical Support Package (TSP) is the complete back-up documentation which explains an innovation announced in a NASA Tech Brief.

** Numbers in parentheses refer to NASA case files from which these summaries were prepared.

APPENDIX F

to the

STATEMENT OF

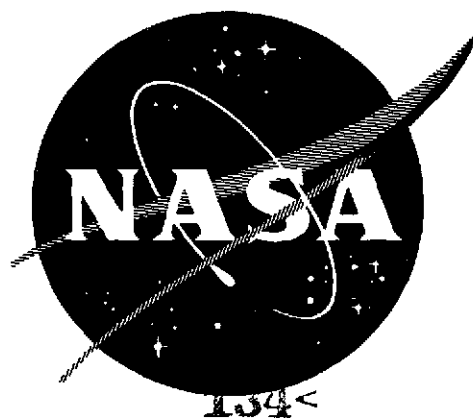
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Health Care

THE NASA ROLE IN MAJOR AREAS OF HUMAN CONCERN

HEALTH CARE



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THE NASA ROLE
IN MAJOR AREAS OF HUMAN CONCERN:
HEALTH CARE

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PREFACE

Understanding the social significance of America's civilian aeronautics and space effort has become increasingly difficult during the past five years. Whereas the missions of the National Aeronautics and Space Administration once figured prominently in discussions of public issues, increased interest in other national priorities has come to compete with, and often to dominate, concern about those missions. The study which generated this presentation was undertaken to facilitate more thoughtful discussion of NASA's activities by exploring how the achievement of mission objectives has contributed to beneficial changes occurring in six areas of major national interest: communication, transportation, environmental quality, safety, health care and work.

This statement focuses attention on the area of health care. After introducing some of the general factors that have affected progress in this area, NASA program elements are examined to illustrate relevant points of contact. Interpretive steps are taken throughout the statement to show a few of the more important ways people's lives have been affected as a result of the work of NASA and other organizations functioning in this area. The principal documents used and interviews conducted are identified after the conclusion of this statement.

This statement, it should be noted, is incomplete in many respects, primarily because it reflects only a small number of the technical, economic, and social forces affecting American life. Taken as a summary statement, however, it hopefully will provide a useful basis for better understanding NASA's role in the national attempt to improve the delivery of health care services.

HEALTH CARE: EXPANDING THE BIOMEDICAL TECHNICAL BASE

Good health is one of the most widely sought, yet least permanent, conditions man strives to attain. The National Center for Health Statistics reports that seven out of ten Americans visited their physicians at least once during 1971, and that approximately one in ten were hospitalized at least once.¹ The cost for the country's health services

Health care requirements are extensive and costly.

totaled some \$83 billion, roughly 7.6 percent of the nation's gross national product; by contrast in 1960 the nation's health bill came to \$25.9 bil-

lion, or 5.2 percent of GNP.² Despite such massive and increasing expenditures, major health problems remain unresolved. Cancer, heart disease, sickle cell anemia, mental disorders, drug addiction, and aging plague millions. An estimated 81,000 professional workers were engaged in medical and health-related research in 1972 to develop more powerful means of solving these and other serious health problems.³

Public participation in health care programs has changed greatly since World War II.⁴ In the late 1940's, new group health insurance plans

Health care now means maintenance as well as cure.

offering financial protection against illnesses and health care came to be viewed by many as being almost exclusively the treatment of injury, sickness,

disease. Recently, however, the idea of health care has been broadened to include health maintenance through proper nutrition and physical fitness and periodic examinations for early disease detection with a renewed interest and emphasis on preventive medicine.⁵

Specialization and the high costs of medical care have been major forces behind the widening commitment to health maintenance. So, too, have

Many forces support health maintenance.

improvements in preventive medicine.⁶ By developing disease profiles and routinely analyzing physiological processes, predictive medical techniques have emerged

as powerful influences for health maintenance. There is now sufficient evidence, for instance, that a strong link exists between cigarette smoking and lung cancer.

Today's expanding population has high expectations for good health fueled by rapid medical advances and by the emerging feeling that good health is a right rather than a privilege. That

Public expectations are forcing action against health problems.

the subject has become one of intense public interest is clearly evident in the fact that five major health care proposals

are now before Congress. The scope of these proposals is indicated by the estimate that, by 1975, the most comprehensive of these plans could cost taxpayers about \$67 billion annually.⁷

Against the background of forces affecting health care, another major problem has arisen. It concerns the difficulty of improving the quality of health care while trying to meet a sharply increasing demand for such care. It is this quality-quantity problem arena that NASA programs have

NASA programs help improve both the quality and quantity of services available.

made largely unanticipated contributions.

The combination of medical research, particularly in new areas of physiology and biology necessitated by space flight, together with systematic develop-

ment of means for the remote acquisition, monitoring, and interpretation of physiological processes during flight, have contributed some of the technology needed for improving both the quality and the quantity of health care. The technical innovations, some of which are described below, provide the Nation not only new or improved health care tools, but they also provide greater assistance for more people concerned with maintaining or regaining a healthy condition.

Discovering the Healthy Man

Major interest in the total physiology of healthy persons had its beginnings in military flight training.⁸ The combination of aging individuals, expensive equipment, and urgent situations forced new attention upon the physiological and psychological aspects of man under stress. Solving

Military programs stimulated interest in the healthy individual.

such problems as pilots blacking out under high gravity forces or becoming unconscious or disabled with lack of oxygen became essential to safe and effective military aviation. The ques-

tions multiplied as aircraft performance was improved, as the number of older pilots increased, and as commercial aviation became more important in the American way of life.

With the advent of manned space flight, it became crucial to define precisely an individual's optimum health state, physical and mental, in order

Space flight generated the need to define the healthy condition.

to assure adequate performance in environments outside the Earth's atmosphere.⁹ This requirement has helped broaden medical research from a primary focus upon

diseases and corrective procedures to include a deliberate study of good health with clear definitions of what man's normal functioning specifically entails.

One of the most significant outcomes from this research is found in a new understanding of the influence of severe environments on human functioning. Most physicians study the response of abnormal individuals to normal environments, while flight surgeons study normal individuals to abnormal environments. Often, abnormal environments rapidly induce symptoms and characteristics of a wide variety of diseases and disabilities in healthy individuals and healthy organisms.

In recent years, there has been growing concern that the sedentary aspects of modern industrial society may predispose many Americans to cardiovascular diseases.¹⁰ Many studies have demonstrated a strong relationship between the intensity, duration, and frequency of physical

The relationship of inactivity to disabilities concerns researchers.

activity performed by an individual and mortality from heart disease: ordinarily the greater the activity, the lower the mortality rate. The

consequences of prolonged bed rest can include muscle atrophy, brittle bones, circulatory difficulties, kidney stones, blood clots, and pneumonia; all of these threats are clinically recognized so that early ambulation of the recuperative patient has been emphasized more and more in the last 25 years.

Manned space flights have demonstrated that a certain amount of physiological adaptation occurs during prolonged weightlessness that may have adverse effects when reentering the Earth's atmosphere.¹¹ With weightlessness and loss of gravity, for example, there is a redistribution of body fluids which may alter acutely or chronically the sensors

Gravity effects have been related to body processes.

regulating blood distribution in the body. On returning to Earth, this problem may create readjustment difficulties for the astronaut. Just as

congestive heart failure may disrupt the functioning of cardiac receptors, prolonged weightlessness or complete inactivity may cause alteration of the mechanisms responsible for maintaining the proper circulating blood volume.

Scientific understanding of this condition and its treatment owes a great deal to research performed in aerospace medicine on the mechanics of circulation related to gravity effects on the human body. Scientists at NASA's Ames Research Center, for example, in cooperation with the National Institute of Health and researchers at Stanford University and

NASA, Stanford, and the Mayo Clinic jointly have studied cardiovascular activities.

the Mayo Clinic, have developed computer techniques to present a visual display of the contracting heart.¹² The computer input is obtained by injecting an X-ray opaque dye into the heart and converting

the resulting X-rays into digital data. The new computer technique is being used in selected research centers around the country to evaluate the effects of blocked coronary vessels in heart patients. This new diagnostic method enhances the use of angiocardiology and holds promise for better diagnosis and understanding of cardiovascular diseases.

Confinement and relative inactivity are other specific examples of common patient environments in which the normally occurring physiological effects have much in common with specific effects induced by weightlessness.

Inactivity and weightlessness produce similar effects.

Recognizing similarities between these conditions has stimulated important advances in patient care. For example, in long-term bed rest studies supported by

NASA and the U. S. Public Health Service, new treatments have evolved for osteoporosis, the thinning of bone structure due to calcium loss. During these investigations, researchers developed the first method for predicting the susceptibility of a patient to osteoporosis.¹³

Over the past few years, NASA's development of new and better means of continuously measuring human physiological responses has injected the Agency into the mainstream of preventive and predictive medicine. The investigation of healthy individuals has thrown new light, for instance, on the nature of the body rhythms. It has long been known

*Continuous monitoring
includes body rhythms
in patient profiles.*

that normal body temperatures decrease by one or two degrees during the night and then rise to a peak during the afternoon. NASA research clearly documented the constant changes occurring

in other physiological and biochemical life processes. With the onset of many illnesses, bodily rhythms often fluctuate unexpectedly. Understanding the broad range of normal physiological rhythms, therefore, is clearly important to predictive medicine. Previously, isolated clinical tests provided only a glimpse, whereas long-term examinations of bodily functions by improved physiological tests and timed biochemical analyses are providing major insights into man's physical nature and his dynamic responses to constantly changing environments.¹⁴

A basic thrust of recent cancer research has been to analyze the nature of rapid, uncontrolled cell growth and the propagation of this condition through the body; these two conditions characterize cancer. As part of their space research mission, scientists in the NASA Langley Research

*Cell-division studies by
NASA scientists are tied
to cancer research.*

Center Molecular Biophysics Laboratory have been investigating the effects of radiation on cell division for several years.¹⁵ Their research has shown that the occurrence of cell division is as-

sociated closely with the electrical potential of cell surfaces: division is more likely to occur with lower electrical surface potentials. From these results, Langley researchers have been able to formulate and test a theory of cell division. Several university research teams are conducting independent investigations based on this theory. If it is substantially verified, the theory should make a major contribution to the understanding of cancerous cell behavior and should help move the nation one step closer to an ultimate prevention or cure of the disease.

One of the most familiar diagnostic tools used in routine medical practice today is the electrocardiograph. This device measures the electrical activity accompanying the rhythmic behavior of heart muscles. Interpretation of the ECG is always related to what is physiologically normal.

When the Public Health Service (PHS) began work in 1957 to automate the

*Automation is employed to
speed use of diagnostic
information.*

analysis of ECG records, the first requirement was to establish normalcy patterns. Working with the Air Force initially, thousands of healthy servicemen were examined, and a computer-based

processing and analysis system was developed. This concept was refined by the Public Health Service, the Air Force, and NASA over the next decade. One of the principal refinements was to make possible real-time computer analyses of ECG recordings.¹⁶ This advance may become particularly important in major surgery, for example, where knowledge about sudden changes in a patient's condition can mean the difference between life and death.

Late in the 1960's, the technology had progressed to the point where a new industry for local analyses of ECG's came to life.¹⁷ More than 500,000 people have had their records screened automatically, thus establishing a new benchmark in the early identification and treatment of heart disease.^{18, 19} This thrust toward automatic analysis of health records has been strongly supported by NASA's research on normal individuals, research that involved both the development of instrumentation and methods for total medical information management.²⁰

Maintaining Adequate Health

Improving physiological measurements is essential for long-term advances in the quality and quantity of medical care, and it is here that NASA-supported research has made a significant contribution. Better measure-

Tools for prediction and prevention are needed for health maintenance.

ment, however, translates into more advanced equipment and larger systems of data and research management. As the Nation's current, large-scale attack on major health problems intensi-

fies, tools for performing tests faster and more accurately must be developed; new testing methods and instruments will be required; and, finally, the capability to interpret and act on the information generated must be improved.

Activities to maintain adequate health are supported internationally by organizations such as the United Nation's World Health Organization and UNICEF, private organizations such as CARE, and through numerous bilateral and multilateral government aid programs. Within the United States, the Public Health Service, the National Institutes of Health and other agencies within the Department of Health, Education and Welfare are involved across the whole spectrum of maintaining adequate health, from nutrition and health education to diagnostic screening programs; in addition, the Department of Agriculture has had a long-term major role in the revolutionary increases in productivity of American agriculture.

In the production of food, new technology has played a fundamental role. Fertilizers, pesticides, and "miracle" strains of wheat and corn have increased production potential many-fold in the last few decades. Now satellites and aircraft are coming into use to identify crop diseases, discover new arable land, and improve weather forecasts used in planning for planting and harvesting.^{21, 22}

Remote sensing and contamination control tools help improve food production and distribution.

Food preservation techniques, so essential for good nutrition, also have been improved significantly in recent years.²³ The food processing industry, in developing foods to NASA requirements for use on long-term space missions, has generated much new information on food

processing, preservation, and nutritional value which is being used for consumer products. To sharply reduce the chances of food-borne infection on space flights, for example, firms that have produced foods for NASA have established special controls and procedures in food production. One such control is the use of "clean rooms," isolated areas where contamination is minimized, to prepare food. Clean room technology has been

significantly advanced by NASA, the Department of Defense and the Atomic Energy Commission. The use of a contamination free environment could lead to elimination or reduction in the need for thermal processing, which often destroys nutritional value, flavor, and color; it could also lead to the incidence of food-borne diseases, which is still a public health problem. Other NASA work on food technology which has general applicability includes identification of dietary requirements to avoid bone demineralization (a problem with bed-ridden patients), contributions to the use of radiation for food preservation, and a low cost method of determining the vitamin content of food.

Adequate health is maintained not only by proper nutrition, but also by frequent diagnosis. In the past decade, automated and computer-created health screening centers have been organized, particularly in support of

*Multiphasic health screening
is demonstrated.*

paid health maintenance programs and large medical institutions.²⁴ For instance, the Kaiser "Multiphasic Health Checkup" was screening 25,000 patients annually in 1965 at a cost of about \$35 per patient. The screening provides an instantaneous computer summary of more than 40 medical measurements obtained during a 2-1/2 hour examination.

NASA was an early contributor to the technology of automated health screening. At the Manned Spacecraft Center in Houston, for example, a program for multiphasic analysis of clinical patients has been operated since the Center was established in 1961.²⁵ Some 5,700 people have been screened routinely during the decade. This work also has affected medical procedures by standardizing results, reproducing tests, defining normals, and developing computer software for records management and data analysis. Among other things, an operational, computerized medical-record system called MEDATA emerged from this work.²⁶

A technique developed at the Goddard Space Flight Center to detect life on other planets is being adopted by researchers at Johns Hopkins University Hospital in Baltimore to help identify urinary tract infection, a malady affecting 1,000 Americans.²⁷

*New developments can make
many tests routine.*

The first step, nearly complete, has been to establish the reliability and repeatability of the technique by comparing its results with those obtained through the standard technique in which cultures are prepared from urine specimens. Results, the second step, also nearly concluded, involves the construction of an automatic apparatus that completes the test in 20 minutes as opposed to the 3 to 5 days involved in the standard test. This apparatus literally makes a diagnostic test routine that formerly was undertaken only after other symptoms of infection indicated the advisability of specific confirmation.

The Whittaker Space Sciences Division of the Whittaker Corporation has used diagnostic and optical instrumentation technology it developed under a NASA contract to build a new instrument for screening potential lead

*Social problems relate
to health problems.*

poisoning victims.²⁸ Lead poisoning is particularly problematic in inner city areas where lead-based paints still take a terrible social and economic toll by causing brain damage in young children. Whittaker has introduced a portable instrument that can rapidly and economically detect the presence of lead in the blood.

At Baltimore City Hospital, the Whittaker unit was used during the past two years to screen approximately 1,000 children; 12 percent were found to have abnormally high levels of lead in their blood.²⁹ Children with a reading above 60 micrograms of lead per 100 grams of blood are placed in convalescent facilities; those above 80 micrograms are placed in intensive care. Use of the machine at Charleston, South Carolina and at Harrisburg, Pennsylvania showed that the tests could be performed rapidly and with few personnel, and that costs were reduced to about \$1.00 per

Efficient equipment developments can meet specific needs.

test from the \$15.00 per test using the usual atomic absorption method. It has been suggested that 12 percent of all ghetto children have a reading of 50

micrograms or greater. After a person's level reaches 60, it can rise very rapidly and cause irreparable harm to the central nervous system. In St. Louis, a demonstration model of the Whittaker instrument was used on about 200 children; 11 percent had a high level of lead indicated, while another 15 percent showed positive readings without lead indicating other serious problems such as sickle cell anemia, poor nutrition, etc.³⁰ Use of the unit is faster than conventional methods and greatly reduces testing trauma. The technologies of power supply, fiber optics, photo-detection, and miniaturization were combined with the laboratory fluorimeter's capabilities to provide this valuable diagnostic tool.

Sanders Associates in Nashua, New Hampshire is marketing a medical data management system that embodies technology developed from the Saturn V prelaunch checkout system.³¹ The medical data system has been tailored to link all map parts of hospital information networks, including laboratories, treatment rooms, admissions, accounting, and dietary kitchens.³² The Kaiser Memorial Hospital in San Francisco uses this system in its pediatric center where 24 cathode ray tube displays provide interactive

Data management systems link hospital units.

data links. The Mayo Clinic in Rochester, Minnesota installed the system about two years ago in its Admissions and Records Department where 130,000 line items per

day are processed. These examples illustrate the technological basis behind improvements in measurement and data management affecting large numbers of people. Population screening is a trend in health care delivery that is clearly in its infancy. Screening will continue to grow as a force in health care because it is much less expensive--socially and economically--to correct potential problems than to treat major disabilities.

Correcting Health Problems

The impact of technology in health care is perhaps most graphically demonstrated in the treatment and rehabilitation phases of a patient's recovery. Open heart surgery, organ transplants, and cancer therapy, to

Serious medical equipment shortages exist.

cite just three examples, require advanced technology of the type embodied in heart-lung machines and in high-energy X-ray generators. The availability of

such expensive equipment sometimes overshadows the fact that less costly instruments, equipment, and appliances that can play such an important role in health care are not generally available.

About four years ago, the National Academy of Engineering recognized that a clear discrepancy existed between the problems in health care delivery and the number of devices available to meet these problems.³³ The Academy established the Committee on the Interplay of Engineering with Biology and Medicine to determine why the discrepancy existed and

The National Academy of Engineering recently studied this problem.

what could be done to correct it.

The committee learned that one of the factors behind the discrepancy was the fact that certain devices, while highly desirable, need only be manu-

factured in small quantities; for other devices, the markets are fragmented, isolated, and difficult to predict, with the result that no manufacturing activity occurs. The committee suggested that one way to close the gap might be to create an agency with primary responsibility to develop and stimulate deployment of biomedical engineering technology.

The NAE committee's recommendation gives an appropriate perspective for viewing the operation of NASA's Biomedical Application Program.³⁴ Three teams, comprised of engineers and scientists and operating from

NASA BATEams help develop needed devices.

nonprofit research institutes, attempt to match technology generated through space-oriented research and development with patient needs identified in medi-

cal research or field practice. Some 77 medical facilities across the country currently participate in this program. In addition to providing information, the application teams oftentimes oversee the development of prototype devices for field evaluation.

An example of a recent collaborative effort between the National Cancer Institute (NCI) and the three Biomedical Application teams illustrates the problem definition and solution process.³⁵ Dr. Edward S. Henderson, head of NCI's Leukemia Service, asked the Biomedical Application Team at the Research Triangle Institute (RTI) in North Carolina to assist in a

NCI and NASA are testing a new device for early detection of shock.

search for a new way to detect the onset of shock in critically ill patients. If not recognized in the initial stages, shock can rapidly prove fatal. Dr. Henderson had determined that conven-

tional methods for detecting initial drops in blood pressure were either unsuitable or unduly disturbing for critically ill patients. A promising solution to the problem was discovered recently when an RTI team member visited NASA's Ames Research Center. An Ames engineer proposed the use of an ear oximeter that measures the oxygen content and pressure level of blood by employing an infrared absorption technique. Impressed with the oximeter's potential, Dr. Henderson and his staff are working with the NASA Application Team to adapt the instrument for shock measurement use.

NASA's research in planetary quarantine, the life sciences, materials, and instrumentation has produced a number of contributions to treatment and rehabilitation technology. Areas of NASA concern for space missions such as contamination-free environments, miniaturized instrumentation,

remote sensing of physiological processes, and closed-cycle life support systems are directly related to basic problems in the medical community and, as a result, have been particularly useful in medical applications.³⁶ Hospitals are beginning to use contamination control techniques originally applied by AEC and NASA.

Clean rooms that practically eliminate airborne bacteria from a room in minutes embody contamination control technology originally developed for the assembly of delicate instruments used in aerospace and atomic energy. To reduce the risk of infection, at least 25 hospitals in the U. S. now apply such technology both in operating rooms and in facilities reserved for patients undergoing radiation and cancer chemotherapy or who have received organ transplants.

In the field of biomedical instrumentation, several NASA developments have found medical application.³⁷ Biotelemetry units developed to monitor the physical condition of astronauts in flight have been adapted and incorporated for use in patient monitoring systems that simultaneously monitor several patients from one nurses' station. Devices originally developed at Ames Research Center and Manned Spacecraft Center allow telemetering of blood pressure, temperature, electrocardiograms, and electroencephalograms without encumbering the patient with lead wires.

Many NASA-developed instruments are finding medical application.

A NASA-developed sensor for monitoring the breathing of animals now performs the same task for infants suffering respiratory difficulties. The sensor monitors the pace and intensity of the

baby's breathing. Information is telemetered to a nursing station where any unacceptable change in the child's breathing sets off an alarm. Engineers at NASA's Lewis Research Center have designed a control system for an experimental artificial heart operated by the Cleveland Clinic; they also have designed a small, inexpensive analog computer to monitor heart patients' blood pressure and cardiac output at St. Vincent's Charity Hospital in Cleveland.

Space materials technology also has found medical application. Carbon composites developed originally for rocket nozzles are being used by researchers as implantable splints, heart valves, and other devices. The carbon material appears to be more compatible with the human body than any other known material and can easily be fabricated into complex shapes.³⁸ Several major medical centers, such as Rancho Los Amigos and

Various materials first used in space vehicles are applied in several different medical areas.

the University of California in Los Angeles, are involved in developing applications for the material. Lightweight epoxy composite materials are being tested for use in a variety of prosthetic devices and appear to hold

promise of significant reductions in the weight and bulkiness of such items. Foam material, originally developed for advanced airline passenger seats to counteract crew discomfort on long flights, is being used experimentally as a decubitus ulcer prevention aid in bed pads, as lining materials for prostheses, and as padding material for burn victims.

A significant new system for correcting health problems involves the use of a satellite to bring medical aid to remote areas. In 1971, Lister Hill Center for Biomedical Communications, initiated an experimental program in Alaska using NASA's ATS-1 satellite.³⁹ The program, which serves 20 villages in the remote Tanana region, provides direct voice communication on a daily basis between physicians in the district medical center and the resident paramedic in each village. These contacts provide medical information of an educational nature for the resident paramedics along with specific directions for procedures in emergency situations. Recently, for example, two emergencies occurred simultaneously in different villages; by using the satellite, a district physician was able to instruct each paramedic so that in both cases lives were saved.⁴⁰

NASA's ATS-1 satellite brings medical aid to remote Alaskan villages.

Biomedical Engineering Improves Health Care Delivery

New developments in health care are helping to bring a longer and better life to millions of people, yet illnesses and deaths that could be prevented by more adequate health care must number in the millions. Many issues must still be addressed in understanding the nature and causes of disease, in maintaining adequate health, and in correcting health problems. Technology, however, contributes not only to solving the purely medical aspects of these problems, but also with wider application to the long-run reduction of medical costs, improvements in food supply and distribution, and advances in preventive medical care through such means as mass health screening programs.⁴¹

Technology provides a basis for better health care.

In a surprising number of program areas, NASA's activities have contributed substantially to the reservoir of knowledge that is being drawn on to improve both the quality and quantity of health care. Satellites have been used to bring medical advice to remote communities; research in life sciences has contributed to the basic understanding of man's physiology; the physiological monitoring and life support of astronauts has found direct application to health problems on earth; and advancements in the fields of instrumentation and materials technology have helped produce badly-needed improvements in health care.

NASA strongly supports the technology generation effort.

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APPENDIX G

to the

STATEMENT OF

Clare F. Farley

Deputy Assistant Administrator for
Technology Utilization

Studies of Impacts and Benefits on NASA Programs

Selected List

Prepared by NASA or under NASA Contract:

1. "A Force for Beneficial Change" - Papers on the NASA role in major areas of human concern.

Prepared to date:

"Safety: Protection through Prevention"

"Environmental Quality: The Quest for Global Improvement"

"Health Care: Expanding the Biomedical Technical Base"

"Transportation: Improving the Alternatives"

"Communication: Developing Better Links Among People"

2. "Economic Impact of Stimulated Technological Change," report by The Midwest Research Institute.
3. "Benefits from NASA - developed Technology," a collection of Press Releases relating to uses of aerospace technology outside the space program.
4. "Medical Benefits from Space Research, NASA Contributions in the Field of Rehabilitation."
5. "Technology Applications Progress Report." Program review document of the public sector applications program, TU Office.
6. "Technology Transfer Profiles." (Reports on the impact of NASA technology in selected areas):

Plastics

Fire Safety

Lubrication

Contamination

Cryogenics

Food Technology

Welding

Patient Monitoring

Fracture Mechanics

Nondestructive Testing

Products, Production and Practices

Visual Information Display Systems

7. "NASTRAN Benefits Analysis" (Summary Volume)
8. "Aerospace Management Techniques" (Report on Commercial and Government Applications).
9. "NASA Contributions to the Advancement to Selected Fields of Technology" (Report).

10. "Space Benefits - Safety." (Pamphlet)
11. "Space Benefits and Older Citizens." (Pamphlet)
12. "A Study of the Impacts and Benefits to Users of NASA Computer Software." (Summary Volume).

Prepared by Others:

1. "For the Benefit of All Mankind." Report of the Committee on Science and Astronautics, House of Representatives, December, 1972.
2. "For the Benefit of All Mankind." (General Electric).

APPENDIX H

to the

STATEMENT OF

CLARE F. FARLEY

Deputy Assistant Administrator for
Technology Utilization

Regional Dissemination Centers and
Application Teams

REGIONAL DISSEMINATION CENTERS

Aerospace Research Application Center
The Poplars Research and Conference Center
Bloomington, IN 47401

Knowledge Availability Systems Center
University of Pittsburgh
Pittsburgh, PA 15213

New England Research Application Center
University of Connecticut
Mansfield Professional Park
Storrs, CT 06268

North Carolina Science & Technology
Research Center
P. O. Box 12235
Research Triangle Park, N.C. 27709

Technology Application Center
University of New Mexico
Albuquerque, NM 87106

Western Research Application Center
University of Southern California
809 W. 34th Street
Los Angeles, CA 90007

APPLICATION TEAMS

Abt Associates, Incorporated
Urban Development Application Project
55 Wheeler Street
Cambridge, MA 02138

Public Technology Incorporated
1140 Connecticut Avenue, NW
Washington, D. C. 20036

Biomedical Applications Team
Southwest Research Institute
8500 Culebra Road
San Antonio, TX 78206

Technology Applications Team
Stanford Research Institute
Menlo Park, CA 94025

Biomedical Applications Team
Research Triangle Institute
P. O. Box 12194
Research Triangle Park, N.C. 27709

APPENDIX H

to the

STATEMENT OF

CLARE F. FARLEY

Deputy Assistant Administrator for
Technology Utilization

Regional Dissemination Centers and
Application Teams

REGIONAL DISSEMINATION CENTERS

Aerospace Research Application Center
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